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DEVELOPMENT OF METHODS FOR ESTIMATION

OF

TAR DELIVERY DISTRIBUTIONS AMONG THE SMOKING PUBLIC

April 15, 1968

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DEVELOPMENT OF METHODS FOR ESTIMATION

OF

TAR DELIVERY DISTRIBUTIONS AMONG THE SMOKING PUBLIC

A. L. Finkner

H. C. Sweeny

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I. GENERAL INTRODUCTION

The description of smoking characteristics of individuals has been of considerable interest in recent years to scientists in many disciplines. In smoking habit investigations, it is of particular relevance to estimate the amount of smoking "exposure" by individuals over specified periods of time. Exposure has been defined and interpreted in many different ways; it may not even be amenable to explicit definition. However, the more precisely it can be defined, the easier it will be to accept or to reject hypotheses relating to smoking exposure. The purpose of this study will be to define an estimate of a measure of exposure which might be called "filter memory", to explore its properties, and to develop procedures for utilizing the filter information. A more specific objective will be cited later.

The first and still most widely used measure of exposure is the number of cigarettes smoked daily by individuals. A number of studies have been conducted using this measure and various inferences concerning relationships have been drawn. It is not the purpose of this report to review exhaustively the literature on the use of the number of cigarettes as a measure of smoking exposure. However, two studies should be mentioned. The first of these was reported in 1956 by Haenszel, Shimkin and Miller entitled "Tobacco Smoking Patterns in the United States."[1]* The second is "Cigarette Smoking and Health Characteristics" published by the National Center for Health Statistics in May 1967.[2] Although both of these studies

*Numbers in square brackets refer to references given on page 85.

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are excellent and comprehensive, their measures of smoking exposure suffers primarily from lack of information on variations between the amount of each cigarette smoked both within and between individuals. Although number of cigarettes smoked per day is a useful measure, some relationships may have been obscured because a more precise technique was not available.

In order to reduce some of the smoking exposure variability, some investigators have measured the length of butts in addition to (or sometimes in lieu of) counting the number smoked. One such study was reported by Hammond.[3] In this particular investigation there was no attempt to relate number smoked with length of cigarette smoked; hence, an individual's smoking exposure could not be estimated. Finkner, et. al.[4] reported for a highly motivated group, estimates of both length and number and developed a regression equation for predicting number of grams "consumed" per day.

Although it is relatively easy to obtain a sample of butts as Hammond did, it is much more difficult to obtain the joint measure of both number and weight from a random sample. Consequently, there are few studies reported which utilize this procedure. Given that such joint measures are possible, there are two main deficiencies in butt length measurements:

(1) some cigarettes may be burned by smoking while others may burn statically, lying in an ashtray or on the ground after they are discarded.

(2) puff volume, intensity and duration may vary from smoker to smoker or even between cigarettes for a given smoker.

An additional measure, designed to further increase the precision of

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smoking exposure estimates, is the number of puffs taken by the smoker while smoking a given cigarette. An attempt to use this measure was reported by Hilding.[5] He observed subjects in a hospital dining room without their being aware of his observations. In addition to number of puffs he measured duration of the puff and also measured the length of the butts. His report covered 28 subjects.

The disadvantages of this type of a measurement are obvious. A subject can be observed only a small part of the day without his knowledge. Awareness that he is being observed may change his smoking habits. Further it will be impractical if not impossible to observe him throughout the full 24 hours, with or without his knowledge. During those parts of the day when he cannot be observed, his smoking behavior may be quite different.

Therefore, if information collected on the filter can be translated into quantitative measures and if these can be related to certain characteristics of the smoke delivered through the filter, a more precise measure of smoking exposure would be available. To follow this line of investigation, the variables to be predicted and the variables used as predictors must be defined. That is

$$y_d = f(x_f)$$

where y_d = the measurement from the delivered smoke,

x_f = the measurement from the filter.

Various candidates are available for both y and x. In this study, y_d will be defined as FTC tars and will be considered as the measure of exposure. Two measures of x_f will be considered: one is the gain in weight of the filter due to deposited particulate matter and the other is the amount of nicotine extracted. These parameters will be defined explicitly

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in succeeding sections and will be used to estimate smoking exposure.

Section II of this report is devoted to the development of a procedure for estimating FTC tars from filter information and to the analysis of the data which were generated to test various hypotheses concerning the procedure. Section III outlines two suggested field studies: the first is a pilot investigation designed to test the feasibility and compatibility of field, office and laboratory procedures. The objective of the second study is to test the difference in average smoking exposure for those individuals smoking 100 millimeter brands and those smoking 85 millimeter brands. If either of these two studies are conducted, measurements on non-filter cigarettes will be limited to number and length of butt. Additional research will be required before information remaining in the butts of the non-filter cigarette can be used to predict delivery through the cigarette.

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II. ESTIMATION OF SMOKING EXPOSURE BY INDIVIDUALS

A. BACKGROUND

A.1 Introduction. The general problem considered here is the estimation of the total amount of smoke, and the total amount of nicotine and other constituents of smoke which smokers draw from cigarettes, per day. By definition, the total material drawn (delivered) from a cigarette and caught on a perfect filter pad is called "total particulate matter," denoted as TPM. There is a certain amount of moisture in this TPM, called "water." The TPM also contains alkaloids; the total alkaloids are called "nicotine." The remaining material will be called "tar" or "dry TPM," so that

$$\text{TPM} = \text{tar} + \text{nicotine} + \text{water}.$$

Estimates of the amount of TPM, tar, nicotine and water emitted from each brand of cigarettes are obtained routinely from smoking machine tests in each of several laboratories. All cigarettes so tested are smoked to a defined butt length under standard smoking conditions.

It has been suggested that the filter on a cigarette may not only act to reduce exposure, but also may serve as a memory and store some information which may be related to the amount of material (TPM, nicotine, tar) which passed through the filter. If true, then one could analyze filters from smoked cigarettes and make inferences about the exposure experienced by the smoker. The development of such estimators, with a study of the characteristics of the estimators, constitutes the main objective of this report.

All such estimates only measure the amount of tar and nicotine drawn from the cigarette; they do not describe any estimate of the amount of

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material contacting or absorbed in any part of the body. All smokers exhale smoke, and vary in the extent of inhalation. Thus it should be made clear that the estimators proposed are designed to estimate the amount of nicotine or tar which would be deposited on a perfect Cambridge filter pad in a smoking machine if that machine were programmed to simulate, exactly, individual characteristics.

Since the estimators will have these characteristics, attention will be turned next to a description of the characteristics of smoking machines and the tests conducted on these machines (Section A.2), and then to a discussion of the characteristics of smokers (Section A.3); this material is presented as background for the major developments, to be given in the succeeding sections.

Part B contains information on the data available from filters and on such characteristics as precisions of analyses. Part C contains the results of special studies on various aspects of the estimation procedure. Finally, estimators are developed and the characteristics of these estimators are examined in Part D. Recommendations for continuation of this work are given in Part E.

The supporting data and reports which form the basis of the material presented here are given in the several appendixes.

A.2 Description of Standard Smoking Machine Tests. As most of the data studied and discussed in this report was obtained on a standard Phipps and Bird smoking machine, discussion will be limited to that machine.

The machine has 20 positions (or ports) at which cigarettes are smoked. Each port is connected to a Cambridge filter pad holder and, by tubing, to a glass syringe. Cigarettes are mounted in the ports. A thread is stretched

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across the cigarette and across the lever arm of a micro-switch. When the fire cone reaches the thread, the thread burns through, releasing the micro-switch lever which, in turn, immediately shuts off the smoking action of that port. The thread is normally set for a butt length of 27 mm or the length of the tipping paper plus 3 mm, if this exceeds 27 mm.

The volume of air pulled into the syringes during each puff, called the puff volume, is adjustable; the "standard" puff volume is 35 cc. The length of time over which this volume is pulled into the syringe is called the puff time, measured in seconds. The standard value of puff time is 2 seconds, although this is also adjustable. If the volumetric flow rate into the syringe could be measured instantaneously throughout a puff, the plot of that curve would describe the inspiration characteristic of the air pump (syringe). However, it should be noted that the inspiration characteristics of the machine measured at the butt end of the cigarette filter will probably differ from the characteristic plot given at the syringe. Hopefully, the difference will be minor, but the magnitude and effect is not known by the authors of this report. The comparisons are based on the assumption that the machine puff volume and time at the cigarette butt end is the same as at the syringe.

The time between the start of successive puffs is called the puff interval; the standard value of puff interval is 60 seconds, although it may be altered in the machine.

The particulate matter drawn through each cigarette is deposited on a Cambridge filter pad. The pad may be analyzed for total particulate matter (TPM) by weighing, and for water and nicotine by chemical analysis. From this, the tar on the pad may be calculated by difference. Similar analyses may be made on the cigarette filter.

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A.3 Characteristics of Smokers. From the limited information available to the authors on the smoking characteristics of individuals, it may be safely concluded that the most important characteristic seems to be the extreme variability, not only between smokers, but also within smokers. The reported results of three studies were examined.

The first study involved 10 males and 10 females, each smoking about one pack of 85 mm cigarettes. Lengths of butts were measured. (A small amount of information on 100 mm cigarette butt lengths were also reported, but the results are excluded here due to the small amount of data available.) Some conclusions from the analysis of this data are:

a) Men tended to smoke to a shorter average butt length (37 mm) than did women (41 mm), but the variability of lengths was so large as to cloud the significance of this difference.

b) The variability of average butt lengths among males (component of between males variance = 41.4 mm^2) was numerically greater than the variability of average lengths among females (component of between females variance = 13.1 mm^2), but not statistically significant.

c) The variability of average butt lengths among males was significantly larger than could be accounted for by the variability of lengths among single butts smoked by (within) individual males. The same is true for females. Two analyses of variance, one for males and one for females, are presented below in Table A.1 to illustrate this conclusion.

d) Neither males nor females smoked cigarettes close to the FTC test length, on the average. There were only about 6% of the cigarettes smoked with lengths equal to or less than the 27 mm

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Table A.1. Analyses of Variance of Butt Lengths.

Source	Males		Females	
	d/f	Mean Square	d/f	Mean Square
Between Individuals	9	852.4	9	301.3
Within Individuals	181	24.3	189	40.0

FTC test length. Only 6 individuals (4 males, 2 females) out of the 20 engaged in the test smoked cigarettes as short as 27 mm.

In the second study examined, C. H. Keith and E. J. Hackney of Liggett & Myers' Research Laboratory devised a glass cigarette holder with a small venturi jet across which the pressure drop could be measured continually. They used the set-up to test the delivery characteristics of 120 smokers. The pertinent results are summarized here. It should be noted that the study was conducted to provide average puff length, puff volume, and puff interval to use in setting the standards for smoking machine tests. Additional interest lies in the variation about those averages.

Thirty test subjects smoked three cigarettes in the instrumented holder and ninety test subjects smoked two cigarettes in the holder. A velocity-time trace was recorded for all puffs from each cigarette. Estimates of puff volume, puff time, and puff interval were obtained for each puff from its trace, and averaged over all puffs for one cigarette. Average data from the second cigarette from all subjects were re-analyzed, with the results shown in Table A.2

The most interesting fact arising from the results concerns the puff interval; an average of 29.7 seconds was measured during the test. The smoking machine uses 60 seconds as the standard condition. Less than 5%

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Table A.2. SUMMARY OF RESULTS ON SMOKING CHARACTERISTICS FROM LIGGETT & MYERS STUDY.

Group	No. in Group	Averages			Standard Deviations			Correlation Coefficients		
		Volume (cc)	Time (sec)	Interval (sec)	Volume (cc)	Time (sec)	Interval (sec)	(Volume) x (Time)	(Interval) x (Volume)	(Interval) x (Time)
Males	82	41.92	1.84	29.52	9.99	0.51	11.05	0.619	0.089	-0.172
Females	38	42.19	1.90	30.00	7.18	0.43	14.68	0.474	0.327	0.080
Total	120	42.01	1.86	29.67	9.16	0.49	12.26	0.586	0.155	-0.083

Group	No. in Group	Extremes of Characteristics					
		Puff Volume (cc)		Puff Time (sec)		Puff Interval (sec)	
		Min.	Max.	Min.	Max.	Min.	Max.
Males	82	22.4	71.6	1.00	3.24	11.1	72.2
Females	38	30.5	60.6	1.21	2.93	10.4	65.0
Total	120	22.4	71.6	1.00	3.24	10.4	72.2

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of the test subjects had a one cigarette average interval equal to or greater than 60 seconds.

The average puff time was found to be 1.86 seconds, with puff time for individuals varying from 1.00 second to 3.24 seconds. The standard used in smoking machine tests is 2.00 seconds.

The average puff volume was 42 cc, ranging in individuals from 22 cc to 72 cc; the machine test uses 35 cc as the standard puff volume. A recalculation of test results from the second cigarette smoked by all individuals gives the regression estimation relation between volume and puff time, on the average, to be

Puff Volume = 17.9 + 13.16 Puff Time (seconds).

The investigators also measured the butt lengths and found an average length of 31.4 mm for the 120 subjects. A comparison of these results with those presented above indicates very significant differences; the average butt length given in the first study was 37 mm for males and 41 mm for females. One main difference between the two studies was that in the Liggett & Myers study, the butt length measured was that butt length to which a smoker would smoke a cigarette held in a cigarette holder. This may or may not be the same as would be found for the same population, when not using holders.

In the third study, W. S. Estes, Jr. and R. C. Lieser of the Phillip Morris Research Laboratory studied the puff volumes, puff durations, and puff frequencies of 30 smokers, smoking seven king size PM cigarettes at different times. They concluded that the measured average volumes were statistically different from the standards used for smoking machine tests.

Their panel consisted of 19 males and 11 females, classified into A, B, C, and D groups according to their daily smoking consumption. Excerpts

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from their data are given below in Table A.3. From their analysis, they

Table A.3. CHARACTERISTICS OF SMOKERS, FROM PHILLIP MORRIS TESTS.

Class	Cigs. Smoked Per Day	No. of Smokers	Puff Vol(cc) Ave.	$\hat{\sigma}$	Puff Time(sec) Ave.	$\hat{\sigma}$	Puff Interval(sec) Ave.	$\hat{\sigma}$
A	1-10	4	37.8	6.7	1.45	0.265	48.8	33.5
B	11-20	10	39.8	5.9	1.77	0.519	39.9	13.1
C	21-30	7	39.3	9.1	1.68	0.320	53.4	17.1
D	31-40	9	47.7	11.3	1.77	0.400	61.1	17.9
Total		30	40.6	8.06	1.66	0.395	50.5	15.2
Males (excluding D group)		19	39.7		1.7		52.8	
Females (excluding D group)		11	38.8		1.7		42.5	

further concluded that:

a) Light smokers (Classes A and B) inspired statistically lower average volumes (39.3 cc) than did heavy smokers (Classes C and D, with average volume of 44.1 cc). The same is true for Classes A, B and C against Class D.

b) Light smokers (Classes A and B) had a lower average puff time (1.68 sec), statistically, than did heavy smokers (Classes C and D with average puff time of 1.73 sec).

c) Light smokers (Classes A and B) had a shorter interval between puffs (42.4 sec) than did heavy smokers (57.7 sec).

d) No differences between average puff volumes, puff times, and puff intervals were detected between males and females.

e) Heavy smokers have larger volumes per puff but take fewer puffs per cigarette than do light smokers, so that the total volume

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per cigarette is about equal for all smokers.

f) The puff volume is largest for the first puff, and decreases linearly with puff number; the observed relationship is

(Volume per puff) = 48.3 - 1.49 (Puff Number).

The smoking machine has a constant puff volume (35 cc) for every puff.

An inconsistency between these last two studies in regard to the puff interval should be noted; the results from Liggett and Myers give an average of about 30 seconds, while the results from Phillip Morris give an average of 50 seconds. It should be remembered, however, that these results were obtained from only a very few test subjects, specially selected.

B. DATA OBTAINABLE FROM FILTERS

As stated above, the basic problem is the estimation of tar and nicotine delivered from cigarettes over some period (say 24 hours) by individual smokers, based on measurements made on butts or filters. Attention is thus turned, in this and in the next few sections, to the information which may be gained from physical and chemical measurements made on butts or filters and on which such exposure estimation will have to be based. Particularly, attention will be focused on the measurements listed below, in the sub-sections indicated:

Measurement of TPM in Filter	Section B.1
Measurement of Nicotine in Filter	Section B.2
Measurement of Water in Filter	Section B.3
Determination of Tar in Filter	Section B.4

B.1 Measurement of TPM in Filters. To determine the TPM in a single filter,

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the filter is amputated from the butt at the end of the tipping paper and weighed. From this is subtracted the weight of filters from unsmoked cigarettes (the tare weight); the difference is the TPM in a filter.

Data are available from two studies for estimation of the characteristics of this measurement. Results from the first study, from Liggett and Myers Research Laboratory, are summarized in Table B.1. In this study

Table B.1. AVERAGE VALUES, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIATION OF TPM ON A FILTER.

Run	No. Puffs	Average Butt Length (mm)	Average TPM mg	Std. Dev.(1) TPM (Average of 5) mg	Std. Dev.(2) TPM (single) mg	Coeff.(3) of Var. %
L1	2	72.30	1.71	1.197	2.68	157
L2	2	72.23	1.68	0.746	1.29	77
L3	4	61.02	2.96	1.645	3.78	124
L4	6	50.96	6.13	1.100	2.46	40
L5	8	38.06	9.22	2.049	4.58	50
L6	10	27.11	15.39	2.448	5.48	36
L7	10	26.92	16.60	2.238	5.00	30

(1) Standard deviation calculated on averages of five cigarettes per port.
(2) Standard deviation, on a single filter basis.
(3) Coefficient of Variation on a single filter basis.

seven runs were made. For each run, 100 RJR moniter cigarettes were smoked in a machine, five cigarettes per port; with twenty ports, there were thus 100 cigarettes smoked per run. The tare weight was determined by weighing 100 pristine filters. The seven runs were made with the number of puffs varying from two to ten.

The average TPM per filter increases at an increasing rate as the butt

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length decreases. The standard deviation of TPM also increases, but appears to increase linearly for this set of data; these results are shown in Figure B.1 as encircled points (⊙). The standard deviations shown in the fifth column of Table B.1 were calculated from averages of the five cigarettes per port; they were multiplied by ($\sqrt{5}$) to yield the standard deviation for individual filters shown in the sixth column of the table. From the plot, the standard deviation is related to length smoked (ℓ) by the approximate relation

$$\hat{\sigma} = 1.1 + 0.07\ (\ell).$$

Another series of data, abstracted from a study performed by Reynolds Tobacco Company, is given in Table B.2. In this set, 100 RJR

Table B.2. RESULTS OF MEASUREMENT OF WEIGHT OF FILTERS.

Length of Butt mm.	No. Filters Weighed	Ave. Wt. Per Filter, mg.	Std. Dev. Per Filter, mg.	Coeff. of Var. %	Notes
85	150	169.8	3.2	1.88	Tare Weight
70	100	172.2	3.5	2.03	
55	100	174.1	3.0	1.72	
40	100	178.4	2.8	1.56	
27	100	184.1	3.6	1.95	

moniter cigarettes were smoked in a smoking machine and weighed; in addition, 150 filters from unsmoked cigarettes were weighed. Thus the tabled data consists of the gross weights; TPM must be obtained by subtracting the tare weight given in the top row of Table B.2. For such cigarettes smoked to a 27 mm butt length, the average weight of TPM in a filter is (184.1-169.8)= 14.3 mg.

The values of TPM and their standard deviations calculated from the

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data given in Table B.2 are plotted as x's in Figure B.1; the average values from the two series agree fairly well except at the shortest butt length.

The standard deviations given in Table B.2 show no clear-cut trends with length smoked, and thus may be averaged to yield a standard deviation of a single measurement:

$$\left\{\left[149\ (3.2)^2 + \ldots + 99(3.6)^2\right]/545\right\}^{1/2} = 3.23 \text{ mg}$$

with 545 degrees of freedom.

The standard deviation associated with a TPM determination will depend upon the number, k, of filters averaged to obtain gross weight and upon the number, n, of filters measured to determine the tare weight. An estimate of this standard deviation of mean TPM would be

$$\hat{\sigma}_{TPM} = 3.23 \sqrt{\frac{1}{k} + \frac{1}{n}} \quad .$$

In the data presented in Table B.2, n = 150 so that an estimated $\hat{\sigma}_{TPM}$ for a determination based on a single filter would be almost equal to the values given in Table B.2. Thus, these values (which are actually standard deviations of gross weight) are directly plotted on Figure B.1, without correction, as x's, and are taken to be the standard deviation associated with TPM.

The coefficient of variation of the determination of TPM would be estimated by the fraction

$$C.V._{TPM} = \frac{(3.23)\sqrt{1 + \frac{1}{n}}}{(14.3)}$$

$$= (.225)\sqrt{1 + \frac{1}{n}} \quad .$$

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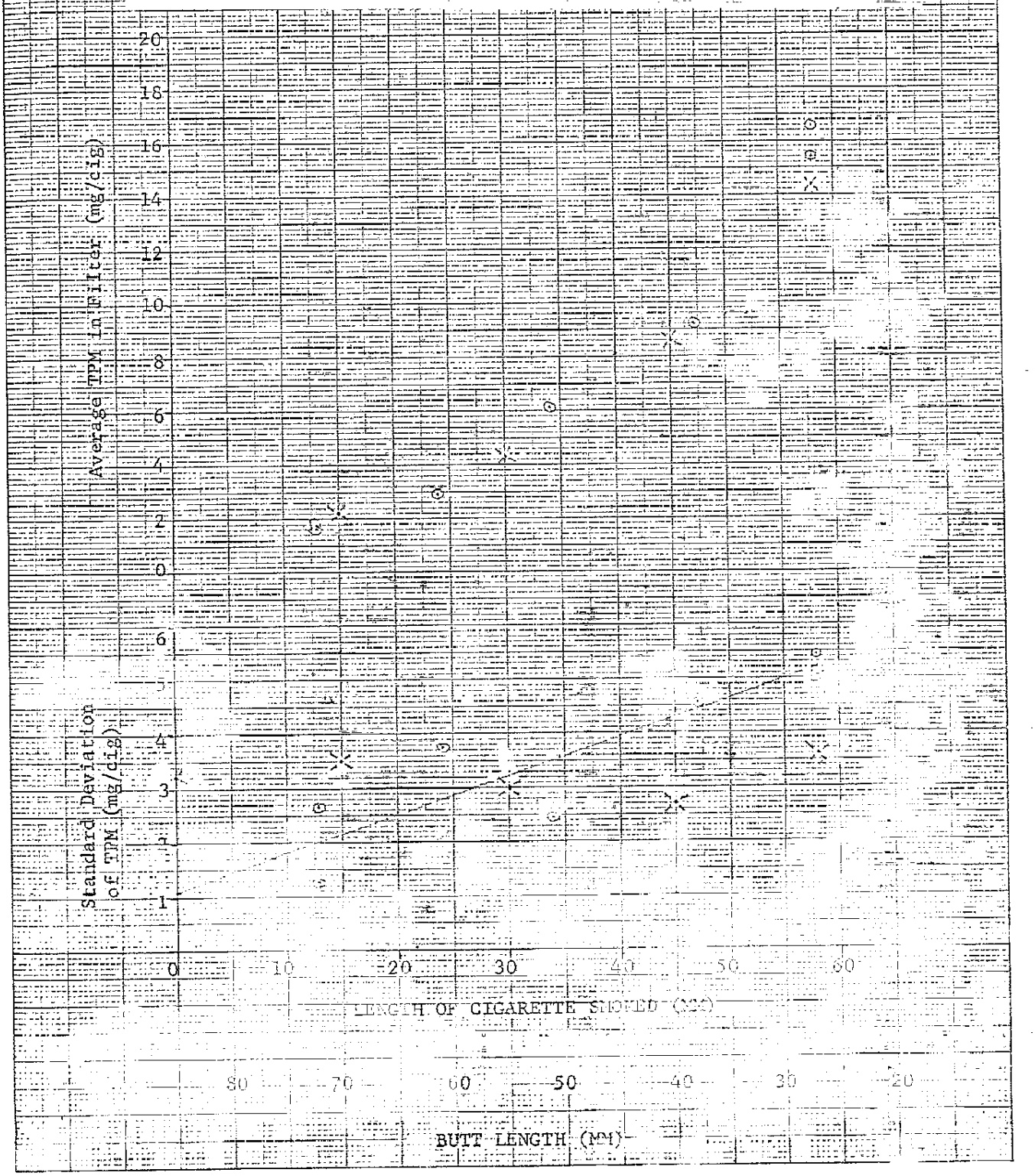
Figure B.1. Values of Average TPM and Standard Deviation of TPM as a Function of Length of Tobacco Smoked for Two Studies Described in Text. Liggett and Myers data are shown as encircled points, R. J. Reynolds data shown as x's.



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Thus, for n quite large, the coefficient of variation is 0.225, and this is a lower limit. For n as small as 25, the coefficient of variation is about 0.23.

If the cigarette is smoked to a 40 mm butt length, which is near the average butt length reported in Section A.3 for test subjects, then the minimum coefficient of variation is found to be 0.376%.

Several attempts were made to construct rational models for describing the concentration of TPM and nicotine in a filter, as a function of the length of cigarette smoked. In general, the data from Table B.1 did not fit these models as well as the data in Table B.2. In the model used here, it was assumed that the weight w of TPM generated from burning a 15 mm length of tobacco plug was constant for each 15 mm length; that each such 15 mm length of tobacco plug had the same filtering efficiency e (expressed as a fraction); and that the efficiency of the filter was denoted by E. Then if TPM from smoking through the i^{th} 15 mm section is denoted by $(TPM)_i$, and if W_i is the weight of the filter after smoking through the i^{th} 15 mm section, then

$$W_o = W_o, \qquad \text{(initial filter weight)}$$

$$W_1 = W_o + Ew(1-e)^3, \qquad \text{(after 15 mm smoked)}$$

$$W_2 = W_o + 2Ew(1-e)^2, \qquad \text{(after 30 mm smoked)}$$

$$W_3 = W_o + 3Ew(1-e), \qquad \text{(after 45 mm smoked)}$$

$$W_4 = W_o + 4Ew \qquad \text{(after 60 mm smoked)}$$

so that

$$(TPM)_i = i(Ew)(1-e)^{4-i}; \; i = 0, 1, 2, 3, 4.$$

The TPM values obtained from Table B.2 were plotted, and a smoothed empirical curve was fitted to the data to allow extrapolation to a butt

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length of 25 mm; then the model given above was fitted to the data. Estimates of parameters obtained were: (Ew) = 3.9, e = 0.27, which gave the following results:

Length Smoked	Data (mg)	Predicted	Difference
15	172.2	171.3	0.9
30	174.1	174.0	0.1
45	178.4	178.4	0.0
60	185.3*	185.4	-0.1

* (extrapolated)

The agreement is remarkable.

The TPM data from Table B.1 was plotted and a smoothed empirical curve was fitted to permit estimation of TPM at 15 mm, 30 mm, 45 mm, and 60 mm smoked lengths. These interpolated values were used to fit to the model given above; this fit gave parameters: (Ew) = 4.24, e = 0.278 (which is remarkably close to the value of e found above.) To compare the model values with actual data, the predicted values from the model were fitted to a smoothed empirical curve and values found at the actual butt lengths observed in Table B.1. The following results were obtained:

Butt Length mm	Observed TPM mg	Predicted TPM mg	Difference mg
72	1.70	1.40	0.30
61	2.96	3.00	0.40
51	6.13	5.60	0.53
38	9.22	9.80	-0.58
27	16.60	15.80	0.80

The agreement, although not as good as in the first case, is not bad enough to warrant rejection of the model form, especially in light of the data manipulation required to fit the model.

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B.2 Measurement of Nicotine in Filters. Alkaloids are extracted from filters with methanol and are either analyzed by

a) a distillation, followed by a U.V. analysis (the FTC method),

or

b) an AutoAnalyzer cyanogen bromide method.

The method of extraction was studied at the Liggett & Myers' Research Laboratory and the results are presented in Table B.3. Twenty cigarettes

Table B.3. RESULTS FROM EXTRACTION STUDY. THE TOP ENTRY IN EACH CELL IS AVERAGE NICOTINE, THE MIDDLE ENTRY IS STANDARD DEVIATION OF INDIVIDUAL NICOTINE VALUES, THE BOTTOM ENTRY IS THE NUMBER OF FILTERS ANALYZED.

No. of Puffs		Method of Extraction Elution	Shaking
2	$\bar{x}$	0.084	0.101
	$\hat{\sigma}$	0.007	0.009
	n	10	10
10	$\bar{x}$	0.706	0.830
	$\hat{\sigma}$	0.090	0.130
	n	9	10

were smoked for 2 puffs and twenty were smoked for 10 puffs. Each set was divided into two groups of 10 cigarettes each, and the nicotine was extracted from one group by elution (gravity flow of 5.0 ml. of methanol through each filter) and from the other group by shaking for one hour in 5.0 ml. of methanol. Nicotine values were measured by the AutoAnalyzer method.

At two puff smoking, the difference in nicotine values between extraction methods is (0.101 - 0.084 = 0.017 mg), and the standard deviation of the difference is 0.0035 mg, giving a t-value of approximately 5,

Source: https://www.industrydocuments.ucsf.edu/docs/yxgk0001

A.3 Characteristics of Smokers. From the limited information available to the authors on the smoking characteristics of individuals, it may be safely concluded that the most important characteristic seems to be the extreme variability, not only between smokers, but also within smokers. The reported results of three studies were examined.

The first study involved 10 males and 10 females, each smoking about one pack of 85 mm cigarettes. Lengths of butts were measured. (A small amount of information on 100 mm cigarette butt lengths were also reported, but the results are excluded here due to the small amount of data available.) Some conclusions from the analysis of this data are:

a) Men tended to smoke to a shorter average butt length (37 mm) than did women (41 mm), but the variability of lengths was so large as to cloud the significance of this difference.

b) The variability of average butt lengths among males (component of between males variance = 41.4 mm^2) was numerically greater than the variability of average lengths among females (component of between females variance = 13.1 mm^2), but not statistically significant.

c) The variability of average butt lengths among males was significantly larger than could be accounted for by the variability of lengths among single butts smoked by (within) individual males. The same is true for females. Two analyses of variance, one for males and one for females, are presented below in Table A.1 to illustrate this conclusion.

d) Neither males nor females smoked cigarettes close to the FTC test length, on the average. There were only about 6% of the cigarettes smoked with lengths equal to or less than the 27 mm

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2, 4, 6, 8, and 10 puffs, and nicotine analyses made by the Autoanalyzer method. In the second set, generated by R. J. Reynolds, four test runs were made; 50 RJR moniter cigarettes were smoked, 5 cigarettes per port, to predetermined butt lengths. Filters, with tipping paper removed, were analyzed by the FTC method. The data for these runs is given in Table B.5.

Table B.5. RESULTS OF ANALYSIS FOR NICOTINE FROM FILTERS.

Butt Length (mm)	Tobacco Smoked (mm)	No. of Puffs	Average Nicotine, (mg/filter)	Std. Dev. of Nicotine	
				Average of[1] five (mg/filter)	Individual[2] (mg/filter)
70	15	2.73	0.086	0.010	0.022
55	30	5.10	0.206	0.007	0.016
40	45	7.87	0.324	0.014	0.031
27	58	9.86	0.550	0.018	0.040

[1] Standard deviation calculated on averages of five cigarettes per port.
[2] Standard deviation, on a single filter basis.

It should be noted that port integrity was not maintained throughout the four runs; that is, the actual ports on which cigarettes were smoked for the nicotine analysis varied from run to run which would, if port-to-port differences are present, tend to increase the variability of results.

The data are plotted in Figure B.2; data from Table B.4 are plotted as encircled points; data from Table B.5 are plotted as points inside of squares. Average nicotine values are plotted at the top of the figure and standard deviations are plotted at the bottom, each against length of tobacco smoked.

The variance associated with the average nicotine content from five filters per port analyzed together is composed of two parts: first, a

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variance due to the variation of true values of nicotine on the filters, σ_n^2, but divided by 5 as it is the average of five filters, and secondly, a variance associated with analytical error, σ_a^2.

The fifth column of Table B.4 for 2 puffs gives the standard deviation of an average of 5 filters; squaring the standard deviation and equating it to its expected value gives

$$(0.00511)^2 = \hat{\sigma}_a^2 + \frac{\hat{\sigma}_n^2}{5} \quad .$$

The standard deviations given in Table B.3 are based on the extraction and analysis of nicotine from single filters. For 2 puffs, the variance from Table B.3 is equated to its expected value, giving

$$(0.009)^2 = \hat{\sigma}_a^2 + \hat{\sigma}_n^2 \quad .$$

The last two equations are solved simultaneously, as shown below, to derive an estimate of the analytical error variance:

$$(5) \times (0.00511)^2 - (0.009)^2 = (5\hat{\sigma}_a^2 + \hat{\sigma}_n^2) - (\hat{\sigma}_a^2 + \hat{\sigma}_n^2)$$

or

$$(0.0000496) = 4\hat{\sigma}_a^2,$$

or

$$\hat{\sigma}_a^2 = 0.0000124,$$

which gives

$$\hat{\sigma}_a = 0.0035$$

as the standard deviation of AutoAnalyzer analytical error. This can not be confirmed by the 10 puff values, as melting of the filters reported above casts some doubt on the validity of the estimates of variance for the 10 puff nicotine results.

Consider the plots of standard deviations given in Figure B.2; at the shorter butt lengths, both plots increase in magnitude. At the FTC length,

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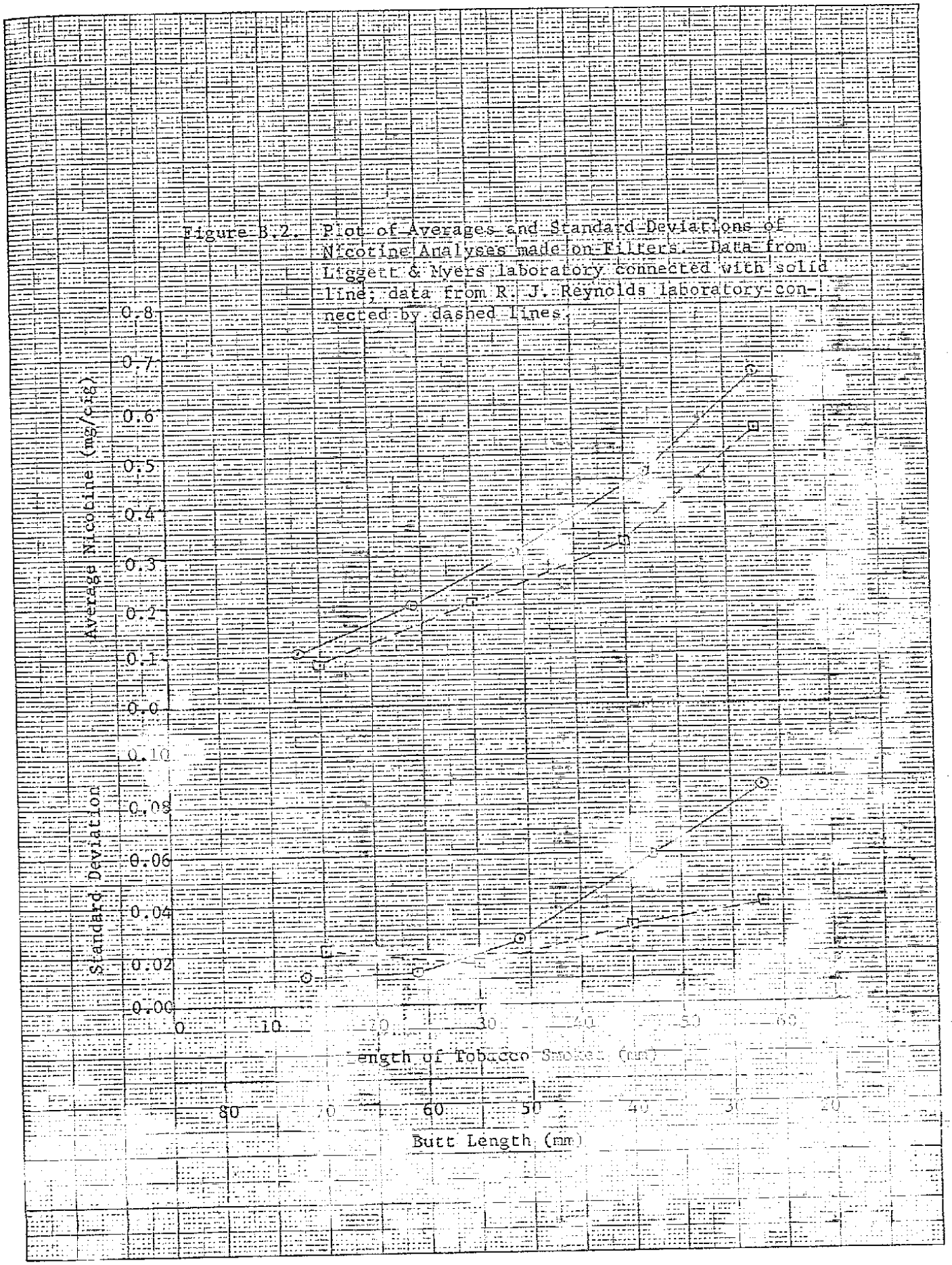

Figure B.2. Plot of Averages and Standard Deviations of Nicotine Analyses made on Filters. Data from Liggett & Myers laboratory connected with solid line; data from R. J. Reynolds laboratory connected by dashed lines.

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the ratio of the standard deviations, squared, is: F = 4.68, which is significant at the 0.05 level. Thus, the standard deviation for the two sets of data are significantly different at the FTC butt length. At the longest butt lengths, the ratio of the standard deviations, squared is: F = 3.85 which is also statistically significant.

The plots of average nicotine values increased non-linearly with increasing lengths smoked. They differ, it would appear, by an almost constant fraction, the nicotine values from Table B.5 being about 82% of the values from Table B.4. Since both sets of data were obtained on RJR moniter cigarettes, one must conclude that the observed differences in standard deviations and means were due to inter-laboratory differences or to analytical differences.

The model fitted to TPM values in Section B.1 may be fitted to the values of nicotine; that model, it will be recalled, is summarized by:

$$(\text{nicotine})_1 = (Ew)(1-e)^3 \qquad \text{(after 15 mm smoked)},$$

$$(\text{nicotine})_2 = 2(Ew)(1-e)^2 \qquad \text{(after 30 mm smoked)},$$

$$(\text{nicotine})_3 = 3(Ew)(1-e) \qquad \text{(after 45 mm smoked)},$$

$$(\text{nicotine})_4 = 4(Ew) \qquad \text{(after 60 mm smoked)}.$$

Values of nicotine were interpolated and extrapolated from curves fit to the data given in Table B.4. The model was fitted, giving parameters: $(\hat{Ew}) \approx 0.177$, $\hat{e} \approx 0.16$, with following results:

Length smoked (mm)	Estimated Nicotine (from data) mg.	Predicted Nicotine (from model) mg.	Difference mg.
15	0.125	0.106	0.019
30	0.262	0.253	0.009
45	0.435	0.448	-0.013
60	0.718	0.708	0.010

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The data from Table B.5 was next fitted to the model. First, the value $\hat{e} = 0.16$ was assumed (based on the results found above) and a value of $(\hat{E}w) = 0.82 \times 0.177 = 0.1487$, based on the parameter found above and on the noted fact that the data were in the ratio of 82%. This model gave the results shown below:

Tobacco Smoked (mm)	Observed Nicotine (mg)	Predicted Nicotine (mg)	Difference in Nicotine (mg)
15	0.086	0.086	0.000
30	0.260	0.205	0.001
45	0.324	0.366	-0.042
60	0.590*	0.582	0.008

* by extrapolation

The fit is remarkable, based as it is on assumed parameters. When the two parameters are determined from the data given in Table B.5, one method of fitting the model gives the estimator $(\hat{E}w) \approx 0.1475$, $\hat{e} \approx 0.1645$, with the following results:

Tobacco Smoked (mm)	Observed Nicotine (mg/cig)	Predicted Nicotine (mg/cig)	Difference (mg/cig)
15	0.086	0.086	0.000
30	0.206	0.206	0.000
45	0.324	0.370	-0.046
60	0.590*	0.590	0.000

*by extrapolation

Thus, three of the four points fell exactly (to three decimal places) on the line given by the model. The best fit to this data, in this sense of minimizing the sum of squares of deviations, is obtained when the parameters have value $(\hat{E}w) = 0.1437$, $\hat{e} = 0.211$; in this case, the following

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results are obtained:

Length of Tobacco Smoked (mm)	Observed value of nicotine, (mg/cig)	Predicted values of nicotine (mg/cig)	Difference (mg/cig)
15	0.086	0.071	0.015
30	0.206	0.180	0.026
45	0.324	0.340	-0.016
60	0.590*	0.575	0.015

*extrapolated value

In summary, all of these show encouragingly good fits of the data to the model. Application of approximate statistical tests of goodness of fit to the results indicate that the deviation from fitting data from Table B.4 are within statistical tolerance. This is not true for the data from Table B.5; these showed significant lack of fit, statistically. In that Table, the value of nicotine at 45 mm butt length was the one which was consistently out of line and may reflect an error of some type. (Confirmation of this would seem to appear in a plot of pad nicotine and filter nicotine from those runs.) On the other hand, it is noted that the deviation of 45 mm butt length are negative in both sets of data, which may indicate that the model does not adequately reflect actual curvature of nicotine versus length smoked at that point.

B.3 Measurement of Moisture in a Filter. Only meager information is available on the measurement of moisture in filter plugs; the data discussed here was obtained from the studies conducted at R. J. Reynolds Laboratory. In that study, the moisture content was measured on fifty filters, five filters per port, at a variety of butt lengths. The data is displayed below in Table B.6 and graphed in Figure B.3. It appears

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Figure B.3. Plot of Water in Filter versus Length of Tobacco Smoked. Two standard deviation limits about averages are shown by vertical lines.

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Table B.6. VALUES OF MOISTURE CONTENT VERSUS BUTT LENGTH, FROM STUDIES CONDUCTED AT R. J. REYNOLDS TOBACCO CO.

Butt Length mm	Average Moisture mg	Std. Dev.(1) (average of 5) mg	Std. Dev.(2) (individual) mg	Coeff. of(3) Var. (individual) %	Notes
85	3.970	0.31106	0.692	17.4	not smoked
70	3.680	0.16613	0.369	10.0	
55	3.610	0.09433	0.210	5.8	
40	3.760	0.20099	0.447	11.9	
27	4.290	0.19723	0.438	10.2	

(1) Standard deviation calculated on averages of five cigarettes per port.
(2) Standard deviation, on a single filter basis.
(3) Coefficient of Variation on a single filter basis.

that the moisture content decreases, both in average level and in variation, for the first few puffs. This may be due to the drying effect of warm smoke which would tend to decrease the standard deviation. The moisture content increases sharply during the last 13 mm smoked. This is a statistically significant increase over the value of moisture obtained at 55 mm butt length. Also shown in Figure B.3 are the $\pm 2\hat{\sigma}$ limits, where the values of $\hat{\sigma}$ are standard errors of the means of the ten groups of five. It should be noted further that the moisture content of filters of cigarettes smoked by humans may possibly exhibit higher averages and variabilities, depending on the smoking characteristics of individuals. Some people tend to wet the end of cigarettes with saliva, which may be absorbed into the filter. Doubtless, this will add to difficulties in determining moisture in filters.

B.4 Measurement of Tar in Filters. Tar is estimated by difference, according to the definition given above:

$$\text{tar} = \text{TPM} - \text{nicotine} - \text{water}.$$

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To obtain the estimate of tar, analyses must be performed for TPM, nicotine, and water. Very little information is available on the characteristics of variation of tar with length smoked, or of the variability of the estimation procedure; the available data will be described and analyzed below.

Since the estimate is made by difference, the variance of the estimate is given by

$$\begin{aligned}\text{Var(tar)} = {} & \text{Var(TPM)} + \text{Var(nicotine)} + \text{Var(water)} \\ & - 2\,\text{Cov(TPM, nicotine)} - 2\,\text{Cov(TPM, water)} \\ & + 2\,\text{Cov(nicotine, water)}.\end{aligned}$$

In estimating tar on pads, it has been noted that, in general,

$$\text{Var(tar)} \leq \text{Var(TPM)} + \text{Var(nicotine)} + \text{Var(water)},$$

so that

$$\text{Cov(TPM, nicotine)} + \text{Cov(TPM, water)} - \text{Cov(nicotine, water)} \geq 0;$$

however, it is not known whether this holds true for the estimation of tar in filters.

The one series of data available comes from studies conducted by R. J. Reynolds and consists of four runs made on a smoking machine; 100 RJR moniter cigarettes per run, 5 cigarettes per port, were smoked to 27 mm, to 40 mm, to 55 mm, and to 70 mm butt lengths. Weights of filters, from which TPM estimates are made, are reported in Table B.2. The filters and pads from 10 of the 20 parts were analyzed for water and the other 10 filters and pads were analyzed for nicotine. The nicotine results are reported above in Table B.5; the water results are reported in Table B.6. It should be noted that the division of the filters from the twenty ports into the two groups varied from run to run, so that any port

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differences are confounded with estimated tar values. Nicotine and moisture determinations were not made on the same filter.

As a consequence of this design, it is not possible to estimate tar from single groups of five filters; only a single estimate of tar from each run may be estimated. Since the covariance between nicotine and moisture can not be determined, the variance of the estimate of tar can not be calculated from the data. Results are given below in Table B.7.

Table B.7. VALUES OF ESTIMATES OF TAR IN FILTER.

Butt Length (mm)	Filter Tar, mg.
70	-1.41
55	0.46
40	4.49
27	9.40

The limitations of estimation of tar in filters is exhibited by the first estimate, which is negative.

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C. SPECIAL STUDIES

Several special studies have been conducted to provide background material for the development of the estimators of delivered tar. These special studies are reported in this section. The first one concerns burn rate of RJR moniters, reported in Section C.1. Next, the effect of static burning on nicotine content of the filter is reported in Section C.2. The effect of delay in measurement is given in Section C.3.

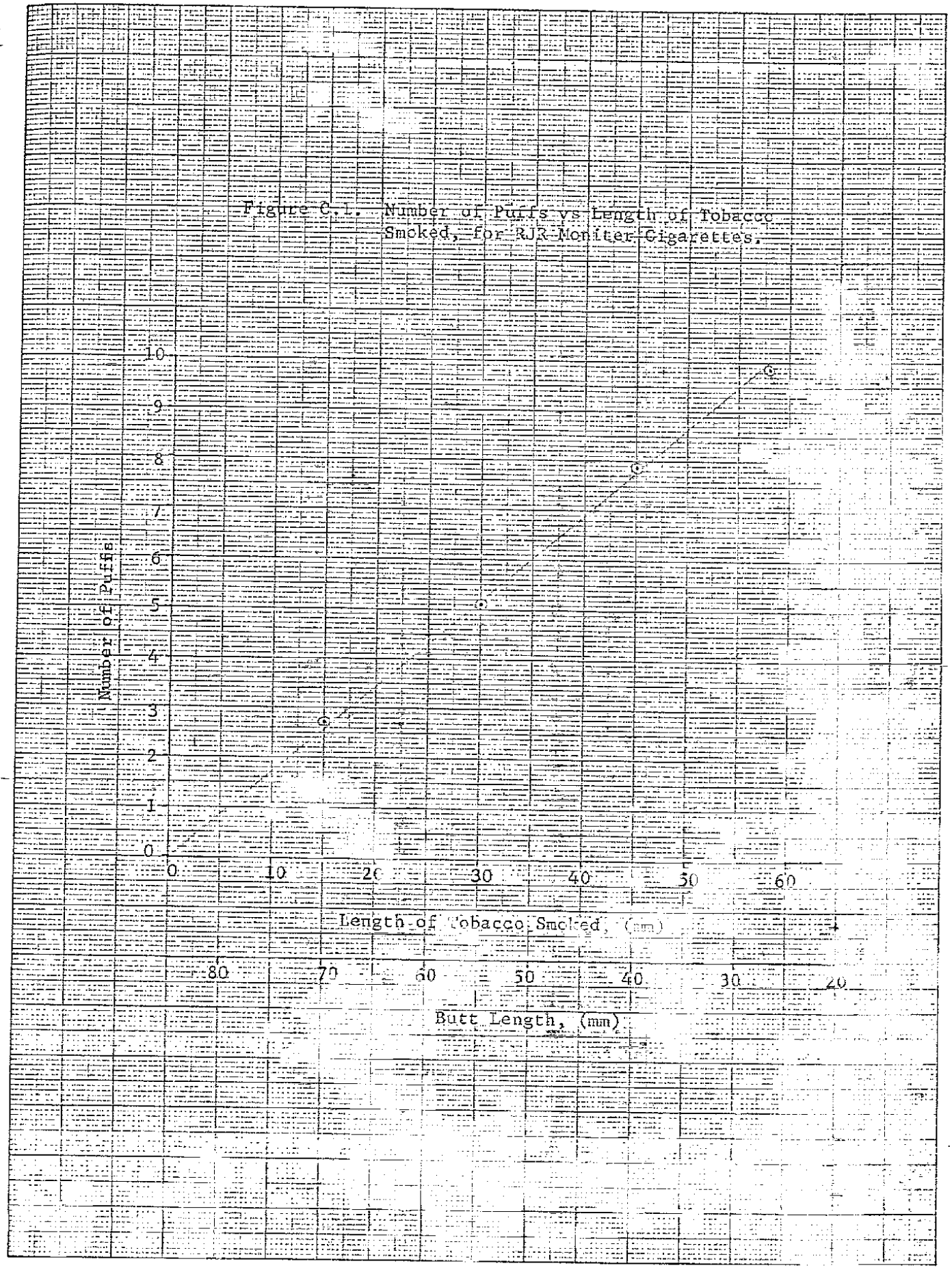
The estimation procedures developed herein are all based on filtered cigarettes. As there is still a large number of unfiltered cigarettes smoked, some consideration has been given by Brown and Williamson Tobacco Corporation to the development of measurements which may be made on the butt of unfiltered cigarettes and which would estimate tar delivery. Some results on the use of total phenol as the predictive indicator are given in Section C.4.

C.1. Burn Rate. Base line data for estimating burn rate of RJR moniters in the R. J. Reynolds Laboratory is given in Table B.5 and described in Section B.2. A plot of length of tobacco smoked versus number of puffs is given in Figure C.1. The estimate of burn rate is 0.173 puffs per mm smoked or 5.78 mm of tobacco per puff. There is no evidence that the lighting puff created any disturbance in this burn rate. Neither is there evidence that the relationship is not linear, nor that the line should not pass through the origin.

C.2. Influence of Static Burn on Nicotine in Filter. If the nicotine content of the filter is to be used to derive an estimate of tar delivery, then it would be hoped that this nicotine content would not be affected by the length of time the cigarette smouldered in an ash tray. If it were, then the estimate of delivered tar would be in error. A series of six

Source: https://www.industrydocuments.ucsf.edu/docs/yxgk0001

Figure C.1. Number of Puffs vs Length of Tobacco Smoked, for RJR Moniter Cigarettes.



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tests were carried out to determine the effect of static burn on filter nicotine content.

In each of the six tests, 100 RJR moniters were smoked in a machine at the R. J. Reynolds Research Laboratory, five cigarettes per port, for a given number of puffs (1, 3, and 5) and then allowed to burn statically to predetermined butt lengths. Nicotine in the filters was analyzed by the FTC method (distillation, followed by U.V. analysis of distillate.) The tipping paper was stripped from the filter before extraction. Data are shown in Table C.1. An analysis of variance was calculated from the

Table C.1. RESULTS FROM STATIC BURN EXPERIMENT.

No. Puffs	Butt Length (mm)	Length of Tobacco Burned			Nicotine in Filter	
		Dynamic[2] (mm)	Static (mm)	Total (mm)	Average mg/filter	Std. Dev.[1] mg/filter
1	65	5.8	14.2	20	0.0190	0.00316
1	50	5.8	29.2	35	0.0200	0.00000
1	40	5.8	39.2	45	0.0195	0.00218
1	27	5.8	52.2	58	0.0210	0.00316
3	27	17.3	40.7	58	0.1050	0.00500
5	27	28.9	29.1	58	0.2160	0.01378

[1] Based on average of 5 filters per port.
[2] Estimated from data given in Section C.1.

data from the first four runs, and is shown below in Table C.2. From this,

Table C.2. ANALYSIS OF VARIANCE FOR STATIC BURN FOLLOWING ONE PUFF.

Source	d/f	Sum of Sq.[1]	Mean Square[1]	F
Between lengths	3	0.4375	0.1458	2.35
Linear	1	0.3025	0.3025	4.89*
Remainder	2	0.1350	0.0675	
Within Runs	76	4.69748	0.06181	

[1] Observed nicotine values were multiplied by 10^2 before analysis; multiply by 10^{-4} to put into original units.

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it is seen that there is a detectable linear trend of nicotine with increasing lengths of static burn; thus, one may conclude that the nicotine in the filter does, indeed, increase with static burn, and that the increase is linearly related to the length of static burn. The rate of increase is calculated as 0.0000463 mg/mm, and the total increase which may be experienced due to static burning from lighting puff to FTC length is estimated at 0.0023 mg. of nicotine, which is a very small amount, and may be considered, practically, as negligible.

A plot of the values of nicotine versus number of puffs from Table B.5 and values of nicotine versus number of puffs from Table C.1 is given in Figure C.2. As seen from this figure, the most direct comparison is at the five puff level; ignoring the fact that the reference value from Table B.5 is actually at 5.1 puffs for the moment, and assuming that they were both at 5.0 puffs, then the static burn nicotine is (0.2160 - 0.2060 = 0.010) mg. higher than the reference value. The standard deviation of this difference is 0.00346 mg. with 38 degrees of freedom; the t-value of 2.7 is significant at the 0.01 level. Thus, here again the static burn is seen to increase, detectably, the nicotine content of the filter, at a gross rate of 0.0003 mg. per mm.

Since the reference value occurred at 5.1 puffs, the test and estimate given above is conservative; the reference nicotine would have been lower had it been measured at 5.0 puffs, which would have increased the difference. Note that at five puffs, the difference in nicotine content is about 5% of the average nicotine when the cigarette burns statically to the FTC length. This may bias the calculations, a point to which reference will be made later.

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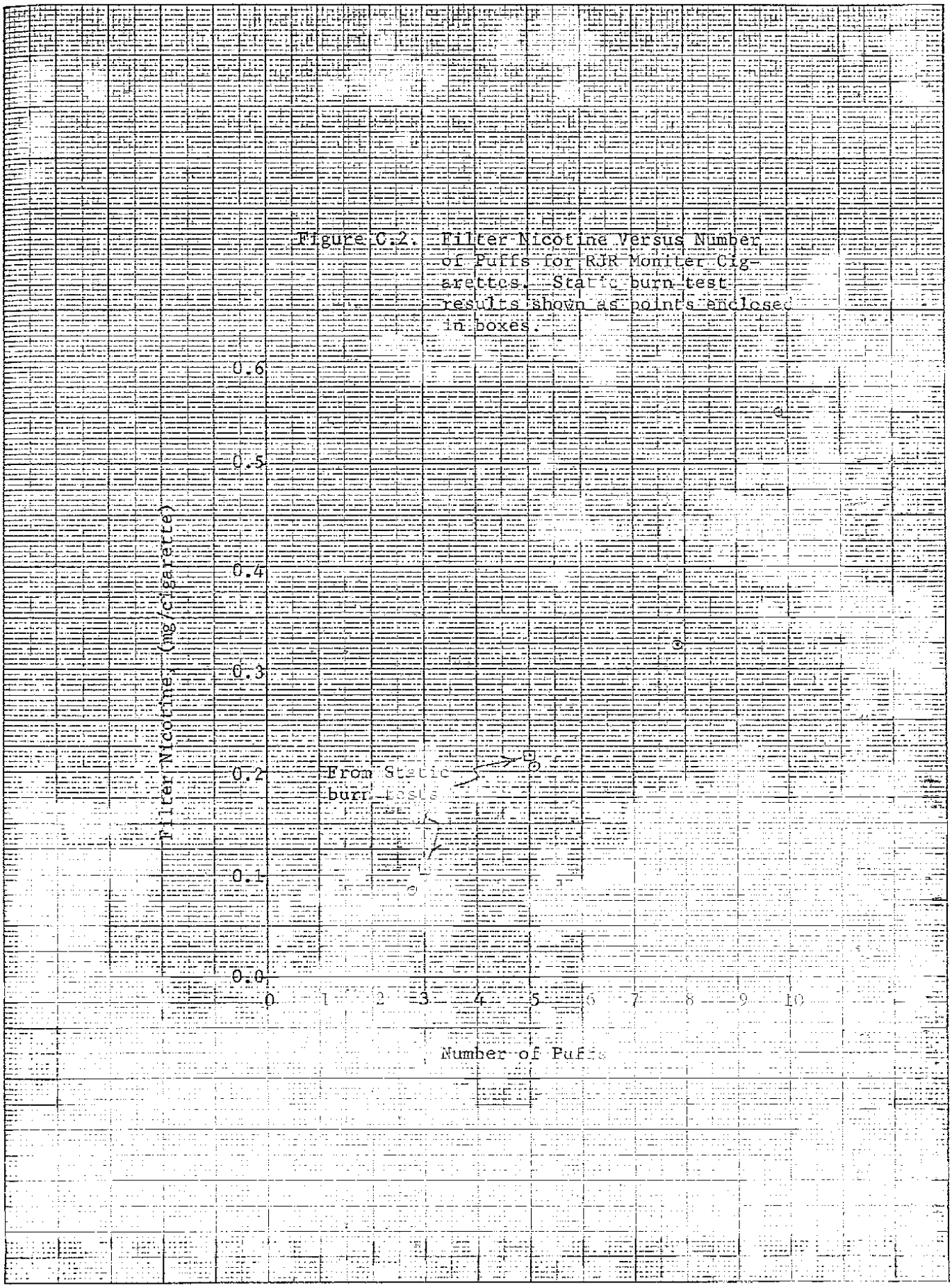
Source: https://www.industrydocuments.ucsf.edu/docs/yxgk0001

Figure C.2. Filter Nicotine Versus Number of Puffs for RJR Moniter Cigarettes. Static burn test results shown as points enclosed in boxes.



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C.3 Effect of Delay in Measurement. If the proposed method is used to study delivery of tar, then there will be some delay between the time cigarettes are smoked and the time the filters are analyzed. The question arises whether the nicotine content of a filter changes if there is significant delay. Three studies were made in the R. J. Reynolds Research Laboratory, each time improving and perfecting the method by which the studies were conducted.

Eleven runs were made on RJR moniters in a smoking machine in the first study. In each run, 100 cigarettes were smoked to FTC length, 5 cigarettes per port. Nicotine contents of filters from three runs were determined immediately; butts from four runs were stored in an open container and butts from the other four runs were stored in a closed container. Butts from one run were removed from the open container and butts from one run were removed from the closed container and each were analyzed for nicotine by the FTC method after storing for 1, 3, 5, and for 7 days. Before extraction but after storage, tipping paper was removed from the filters. Data from this first series is given in Table C.3.

Ignoring the values at 0 time for the moment, the remaining nicotine value under storage were analyzed by the analysis of variance technique, with the results shown in Table C.4. The bottom line is the "within ports" mean square, calculated from the last column of Table C.3. A comparison of this value with the interaction mean square fails to show significance, and this "within ports" mean square is used as a basis of comparison. Other results are:

(a) There is a detectable difference between method of storage, with the nicotine from closed containers averaging 0.003 mg/cig

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Source: https://www.industrydocuments.ucsf.edu/docs/yxgk0001

Table C.3. RESULTS OF FIRST STUDY ON DELAY EFFECTS.

Delay (days)	No. of Puffs	Type of Container	Average Nicotine mg/cig	Std. Dev.(1) of Nicotine(mg/cig)
0	9.55	---	0.615	0.016
0	9.49	---	0.554	0.033
0	9.59	---	0.474	0.024
1	9.96	closed	0.480	0.027
3	9.70	"	0.490	0.024
5	9.81	"	0.464	0.024
7	9.84	"	0.472	0.025
1	10.05	Open	0.500	0.021
3	9.56	"	0.485	0.023
5	9.61	"	0.462	0.018
7	9.81	"	0.471	0.020

(1) Based on average of 5 cigarettes per port.

Table C.4. ANALYSIS OF VARIANCE OF STORED NICOTINE VALUES. (Nicotine values were multiplied by 10^3 before analysis. Multiplying mean squares by 10^{-6} converts them to a "per mean of five cigarettes per port" basis)

Source	d/f	Sums of Squares	Mean Squares	F
Type of Container	1	2160.0	2160.0	4.08*
Length of Storage	3	20060.0	6686.7	12.63**
Linear	1	12800.0	12800.0	24.20**
Remainder	2	7260.0	3630.0	6.88**
Interaction (error)	3	2140.0	713.3	
Total	7	24360.0		
Within Ports	152		528.9	

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Source: https://www.industrydocuments.ucsf.edu/docs/yxgk0001

lower than the nicotine from open containers. Although statistically significant, this is probably not practically important.

(b) There are differences over different storage periods, with an average of 0.006 mg/filter per day decay in nicotine content. This is highly significant. An extrapolation of the regression line back to 0 day delay gives the average estimate of 0.500 mg/filter.

Next, consider the 0 delay time results given in Table C.3. The variation among the average nicotine results is far greater than can be accounted for by within variability, the observed F ratio with 2 and 57 degrees of freedom being 190. The average of these three is 0.571 mg/filter.

Hence, using the value of nicotine extrapolated linearly back to 0 delay, discussed in (b) above, and the average nicotine at 0 delay, 0.571 mg/filter, there would appear to be a difference of about 14% between these values. This difference is both statistically and procedurally significant.

It was hypothesized from the results that nicotine may have migrated to the tipping paper or to the attached tobacco rod during storage, and, as these were discarded before analysis, the stored nicotine results would be biassed. The subsequent tests proved this to be true, and the 14% difference and the detected trend with time provide estimates of the time rate of this migration.

In the second series of studies, ten ports were smoked, five cigarettes per port, for each of 12 runs. Port integrity was maintained. The butts were stored in closed containers, one container storing whole butts, the other container storing the filters with tobacco plug removed, Filters were analyzed by the FTC method, and the tipping paper was not removed

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Source: https://www.industrydocuments.ucsf.edu/docs/yxgk0001

before extraction. Results are given in Table C.5 and an analysis of

Table C.5. RESULTS FROM SECOND EXPERIMENT ON STORAGE DELAY EFFECT.

Delay Time	Nicotine (mg./cigarette)	
	Whole Butt Storage	Filter and Overwrap Storage (tobacco rod removed
0	0.62	0.62
3 hrs.	0.62	0.61
16 hrs.	0.63	0.62
24 hrs.	0.64	0.64
3 days	0.64	0.64

variance is given in Table C.6. The results indicate that:

Table C.6. ANALYSIS OF VARIANCE OF SECOND EXPERIMENT. (Values of nicotine per cigarette have been multiplied by 10^2)

Source	d/f	Sum of Squares	Mean Square	F
Between Times	4	10.60	2.65	17.67**
Between Storage Methods	1	0.40	0.40	
Interaction as error	4	0.60	0.15	
Total	9	11.60		

(a) Storage with or without the tobacco rod caused no discernible difference in nicotine content.

(b) There is a small but detectable difference in filter nicotine per cigarette over time, the estimated rate of increase being 0.00051 mg. per day.

The results from 14 day storage were so different from other results as to warrant discarding them, it being concluded that their differences

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were due to analytical error.

From this, it was concluded that the nicotine in the first study had, indeed, migrated to the tipping paper but not to the tobacco rod.

The third set of runs were made in a different way to eliminate day-to-day variation in analytical technique. In this, five runs were made, with fifty RJR moniter cigarettes smoked per run, five cigarettes per port. Port integrity was maintained. The cigarettes were smoked on different days, arranged so that they could be analyzed on the same days. Results are given in Table C.6. An analysis of variance,

Table C.6. RESULTS FROM THIRD EXPERIMENT ON STORAGE DELAY EFFECT.

Delay Time (days)	Nicotine (mg/cig)	Std. Dev. (mg/cig)
1	0.61	0.02
4	0.61	0.02
7	0.63	0.02
10	0.59	0.02
14	0.62	0.03

comparing the variance between days to the variance within days, gives F=4.4 with 4 and 45 degrees of freedom. The differences are small but significant, statistically. There seems to be no linear trend with time; the significance of the increased variability between delay times apparently represents the added day to day variability of smoking machine testing. This component is estimated at $\hat{\sigma}_t^2 = 0.0017$.

Thus, it is concluded from these three studies that if butts are stored in a closed container and if the nicotine is extracted with tipping paper left on the filter, then there should be no practical effect of delay,

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at least up to 14 days.

C.4 Unfiltered Cigarette Delivery Prediction Study. In an attempt to develop a similar estimation procedure for non-filtered cigarettes, investigations were carried out in the Brown and Williamson laboratories into the relationship between total phenols in the last 20 mm of an unfiltered cigarette and tar on the Cambridge filter pad at different lengths of smoked tobacco. Storage stability tests were also conducted.

The relationship between tar and total phenol appears to be a complex one; for very short lengths of tobacco smoked, tar and total phenol appear to increase about at the same rate. However, when the fire cone approaches the butt end (that is, approaches the last 20 mm section used for analysis) the total phenol increases much more rapidly than does tar.

The correlation

$$\frac{(\text{Tar})}{(\text{Total Phenol})} = (k_1) \times (k_2)^{(\text{Butt length})^{0.04}}$$

was found by Brown and Williamson; this correlation includes butt length as a variable, which would complicate the use of the correlation in predicting tar from butts collected from smokers. It was stated by Brown and Williamson that the correlation is tentative, and more work will be required to confirm it.

Their results also indicated that phenol concentrations in 20 mm butt sections stored in unsealed containers showed significant decreases over a 4 day storage period, but that aging for four days in a sealed container showed no such decrease. These last conclusions should be

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considered tentative, due to the small number of samples used in the aging study.

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D. CHARACTERISTICS OF ESTIMATION OF DELIVERY AT NON-STANDARD CONDITIONS.

Data from smoking machine tests are obtained under a "standard" set of conditions, namely: 35 cc puff volume, 2 sec. puff time, and 60 sec. puff interval. However, the results presented in Section II.A.3 on the characteristics of smokers would lead to the conclusion that individuals have average characteristics different from the standard machine characteristics, as summarized below:

Source	Puff Volume (c.c.)	Puff Time (sec.)	Puff Interval (sec.)
"Standard"	35	2.0	60
Liggett & Myers[1/]	42	1.9	30
Phillip Morris	41	1.7	50

[1/] See Table A.2
[2/] See Table A.3

As seen, the average puff volume of smokers appears to be larger than standard volume, the puff time of smokers seems to be shorter, and the puff interval of smokers appear to be much shorter than standard conditions. These are average characteristics; the behavior of individuals will vary considerably from both standard conditions and from averages.

The major point of interest here, of course, is the effect of different characteristics, exhibited by a smoker on an estimation procedure based on data taken in a machine at standard conditions. The point is of sufficient importance to warrant further discussion.

As stated in the introduction, the estimation procedure will involve a function, f, connecting tar on a Cambridge filter pad and nicotine in a cigarette filter:

$$(\text{tar})_{\text{pad}} = f[(\text{nicotine})_{\text{filter}} \mid V = 35, T = 2, I = 60],$$

and where V, T and I denote puff volume, puff time, and puff interval,

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respectively, and where the vertical line denotes a conditional relationship. That is, the estimation of $(tar)_{pad}$ by the function, f, of $(nicotine)_{filter}$ is conditional on or based on the values of V = 35, T = 2, I = 60. The question arises as to the size and nature of the bias or inflated error of the estimate of tar when other values of V, T, and I are present.

The actual estimation problem will be presented in the next section, (Section E); there, it will be suggested that the estimator may be a proportional model, such as

$$(tar)_{pad} = (\beta) \times (nicotine)_{filter},$$

where β is some constant developed for each brand.

It has been stated, in private conversations with tobacco research scientists, that the nicotine filter efficiency, E, is constant over the smoking length of the cigarette. Since filter efficiency is defined by

$$E = \frac{(nicotine)_{filter}}{(nicotine)_{filter} + (nicotine)_{pad}},$$

then

$$(nicotine)_{pad} = \frac{(1-E)}{E} \times (nicotine)_{filter}$$

which has the same form of relationship as the proposed estimator for tar. If the filter efficiency, E, is indeed a constant, then $[(1-E)/E]$ will also be a constant, the relationship between $(nicotine)_{filter}$ and $(nicotine)_{pad}$ will be proportional, and it could be used to predict nicotine delivery.

Data are available from the studies conducted in the Liggett and Myers Research Laboratory and presented in Table B.4 to permit a small

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test of this proportional model for nicotine; the data is analyzed by regression analysis of variance, with results presented below in Table D.1. The data are too sparce to allow an adequate study of linearity of

Table D.1. SUMMARY OF NICOTINE REGRESSION ANALYSIS OF L & M DATA.

$(\text{nicotine})_{pad} = \alpha_o + \alpha_1 (\text{nicotine})_{filter} + (\text{error})$

$\hat{\alpha}_o = -0.193$; $\hat{\alpha}_1 = 2.106$

$(\text{nicotine})_{pad} = \beta (\text{nicotine})_{filter} + (\text{error})$

$\hat{\beta} = 2.064$

Source	d/f	SS	MS	F
Due to (α_o, α_1)	2	343.101		
Due to β	1	343.055		
Due to $\alpha_o \mid \alpha_1$	1	0.046	0.0460	
About Regression	3	0.107	0.0356	39.12
Total	5	343.208		
Within Tars	95		0.00091	

the relationship to be made; however, the following conclusion may be drawn from the analysis given in Table D.1:

a) The variability between nicotine results from pads from the same number of puffs (denoted as "within" in Table D.1) is significantly smaller than the variability about regression, indicating that the linear model is inadequate, statistically. Further analysis indicates that a third order model with zero intercept is required to reduce the variability about regression to a non-significant value.

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b) In a choice between a general linear model ($y = \alpha_0 + \alpha_1 x$) and a proportional model ($y = \beta x$), the general linear model does not improve the fit significantly, implying that in this choice, the proportional model is equally as acceptable.

Thus, while a proportional model is not a "best fit" and does statistically deviate from the data, it might be adequate for estimation purposes, and will be assumed to be adequate for this discussion.

Data was obtained from the Phillip Morris Research Laboratory on the effects at non-standard conditions; in this series of 32 runs, there were four cigarettes smoked per port, with four ports constituting a run, except at standard conditions, where 8 ports constituted the test. TPMs, nicotines on the pad, and nicotines on the filter were determined for each port from each run. The ratio, (nicotine on pad)/(nicotine on filter), was determined for each test and is given below in Table D.2.

Table D.2. VALUES OF THE RATIO: (PAD NICOTINE)/(FILTER NICOTINE) AT VARIOUS SMOKING CONDITIONS.

Puff Interval (sec)	Puff Time (sec)	Puff Volume (c.c.)			
		15	25	35	45
15	2	1.20	1.46	1.43	1.73
15	4	0.70	1.10	1.38	1.54
30	2	1.18	1.53	1.59	1.96
30	4	1.01	0.98	1.29	1.61
60	2	1.26	1.67	1.74	1.96
60	4	0.91	1.22	1.49	1.55
120	2	1.17	1.76	1.75	2.02
120	4	0.84	1.16	1.52	1.60

This ratio would be an estimate of the parameter β in the proportional estimation model.

Source: https://www.industrydocuments.ucsf.edu/docs/yxgk0001

Reviewing the comparisons given at the beginning of this section, it was seen that observed puff volumes (V) were greater than standard (41 cc and 42 cc versus the standard 35 cc), puff times (T) were less than the standard (1.7 sec. and 1.9 sec. versus the standard 2.0 sec.) and puff intervals (I) were much less than standards (30 sec. and 50 sec. versus the 60 sec. standard). From these considerations, attention will be restricted to the non-standard test conditions: T = 2 sec., V = 25, 35, 45 cc., I = 15, 30, 60.

The values of pad nicotine and filter nicotine (from four cigarettes) from each port were divided to form the ratio, [(pad nicotine)/(filter nicotine)]. These ratios were averaged and their variances calculated; the averages, the variances, and the number of ports for each condition are given below in Table D.3. An analysis of variance for this data is

Table D.3. VALUES OF THE AVERAGE RATIO OF [(PAD NICOTINE)/(FILTER NICOTINE)] VARIANCE OF THE RATIO, AND THE NUMBER OF PORTS USED IN CALCULATING AVERAGES AND VARIANCES.

Puff Interval (sec.)		Puff Volume, (c.c.)		
		25	35	45
15	F	1.49	1.46	1.74
	s^2	0.0079	0.0534	0.0282
	n	4	4	4
30	F	1.54	1.59	1.96
	s^2	0.0061	0.0221	0.0141
	n	4	4	4
60	F	1.68	1.75	1.95
	s^2	0.0061	0.0108	0.0080
	n	4	8	4

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Source: https://www.industrydocuments.ucsf.edu/docs/yxgk0001

given in Table D.4; this analysis is on a per port basis, approximately.

Table D.4. ANALYSIS OF VARIANCE OF RATIOS. RATIOS HAVE BEEN MULTPILIED BY 10^2; MEAN SQUARES MUST BE MULTIPLIED BY 10^{-4}. RESULTS ARE ON AN AVERAGE PER PORT BASIS.

Source	d/f	Sum of Squares	Mean Square
Between Volumes	2	7174.22	3587.11
Between Intervals	2	3200.89	1600.44
Interaction or error	4	497.76	124.44
Total	8	11872.88	
Within Cell	31		165.50

As seen from the table, the interaction term is not as large as the within cell variance; thus, the model would seem to be a simple additive one with no significant interactions. From this, one may predict the value of the ratio at standard conditions and at other conditions. The value at standard conditions is predicted to be 1.71, approximately. At the average shown by L & M (V = 42, I = 30), the average is predicted to be 1.81, which would give a bias to predicted nicotine of about 3.2%. The average smoker, according to the data from Phillip Morris quoted above (V = 41, I = 50) would have a predicted ratio value of 1.87, which would bias the predicted nicotine by about 6.5%.

Thus, the bias of the average smoker's predicted nicotine value would be quite small and probably acceptable. From the above results, a model of the form shown below would seem adequate:

$$\beta = C_{00} + C_{10} V + C_{20} V^2 + C_{01} I + C_{02} I^2 ,$$

where C_{ij} is a fixed coefficient and β is the ratio of pad nicotine to

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filter nicotine. The expected value of β, over the population of smokers, will be

$$E(\beta) = C_{00} + C_{10}\bar{V} + C_{20}\bar{V}^2 + C_{01}\bar{I} + C_{02}\bar{I}^2 + C_{20}\sigma_V^2 + C_{02}\sigma_I^2 ,$$

where $\bar{V}$ and $\bar{I}$ are the population averages of V, I, and where σ_V^2, σ_I^2 are the population variances of V, I. Letting the subscript "s" denote standard conditions; V = 35 cc, I = 60 sec., the value of β used for prediction will be

$$\beta_s = C_{00} + C_{10}V_0 + C_{20}V_0^2 + C_{01}I_0 + C_{02}I_0^2 ,$$

and the difference over the population will be

$$\beta_s - E(\beta) = C_{10}(V_0 - \bar{V}) + C_{20}(V_0^2 - \bar{V}^2) + C_{01}(I_0 - \bar{I}) + C_{02}(I_0^2 - \bar{I}^2)$$
$$- C_{20}\sigma_V^2 - C_{02}\sigma_I^2 .$$

The first four terms on the right hand side represent the bias due to the difference between population averages and standard conditions; the last two terms on the right hand side account for added bias due to individual variation about the population averages. These last terms were not present in the estimates of 3.2% and 6.5% quoted above. However, it is known that the values of C_{02} and C_{20} have opposite signs in the case of nicotine prediction quoted above. The population bias, overall, from the L & M data, would be about 5 - 6%, based on the tentative results given above.

If the same conclusions hold for estimation of tar delivery, the results could well be quite satisfactory.

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DEVELOPMENT OF ESTIMATORS

. The Estimation Problem. The major problem concerns development of ethod for the estimation of tar delivered from a cigarette, based on nicotine content of the filter. The method would be valid for a wide iety of brands of cigarettes smoked to varying lengths. To develop h an estimator, some functional relationship represented by

$$(\text{tar})_{\text{pad}} = f\left\{(\text{nicotine})_{\text{filter}}\right\}$$

needed. If such a relationship were available, one could simply insert otine content to estimate tar on the pad, and one could also calculate variability of the estimate of this tar. Note that either the relanship should be shown to be valid for different brands or that a relanship tailored to each brand must be developed.

Information on nicotine and tar contents on the pad is available for arge number of brands from FTC-like test programs; these data are derived m cigarettes smoked to FTC length, and do not give information to allow imation of the values of pad tar and nicotine at any other lengths. e limited additional information is available on nicotine contents of filter and pad for several brands when smoked to FTC length. These stitute the total data from different brands available for development the estimator.

Limited information is available on RJR moniter cigarettes which may used to relate pad tar content to filter nicotine content at various t lengths; this data is used below to study characteristics of the funcn, $f\left\{\text{nicotine}\right\}$, above.

. The Function: $f\left\{\text{nicotine}\right\}$. One hundred RJR moniter cigarettes,

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at 5 cigarettes per port, were smoked in a machine at the R. J. Reynolds Research Laboratory to 27 mm, to 40 mm, to 55 mm, and to 70 mm butt lengths. TPM values on the pads and filters were obtained for each port (using 150 pristine filters to estimate the tare weight); the cigarette filters and pads from 10 ports were analyzed for nicotine by the distillation method, and the cigarette filters and pads from the other 10 ports were analyzed for moisture content. (The division of the twenty ports into the two groups varied for each butt length.) Since nicotine and water were not measured for the same pad or filter, only a single tar value could be obtained from each run; their variability were not estimable. Results from the four runs are presented below in Table E.1. The

Table E.1. PAD AND FILTER VALUES OF NICOTINE. MOISTURE, TPM, AND TAR AT FOUR BUTT LENGTHS; DATA OBSERVED AT R. J. REYNOLDS RESEARCH LABORATORY.

Butt Length	Nicotine		Moisture		T.P.M.		FTC Tar	
	Filt.	Pad	Filt.	Pad	Filt.	Pad	Filt.	Pad
70	0.086	0.234	3.680	0.300	2.36	5.06	-1.41	4.52
55	0.206	0.569	3.610	0.590	4.28	9.94	0.46	8.78
40	0.324	0.909	3.76	1.37	8.57	16.84	4.49	14.57
27	0.550	1.230	4.29	3.03	14.29	25.30	9.40	21.04

lues measured on the filter have been discussed in Part B of Section II.

The values of pad tar are plotted against filter nicotine in Figure 1. Two functional relationships were fitted to these four points; the rst one is the proportional model:

$$(\text{tar})_{\text{pad}} = \beta \times (\text{nicotine})_{\text{filter}} + \text{error},$$

d the second is the general linear model

$$(\text{tar})_{\text{pad}} = \alpha_0 + \alpha_1 (\text{nicotine})_{\text{filter}} + \text{error}.$$

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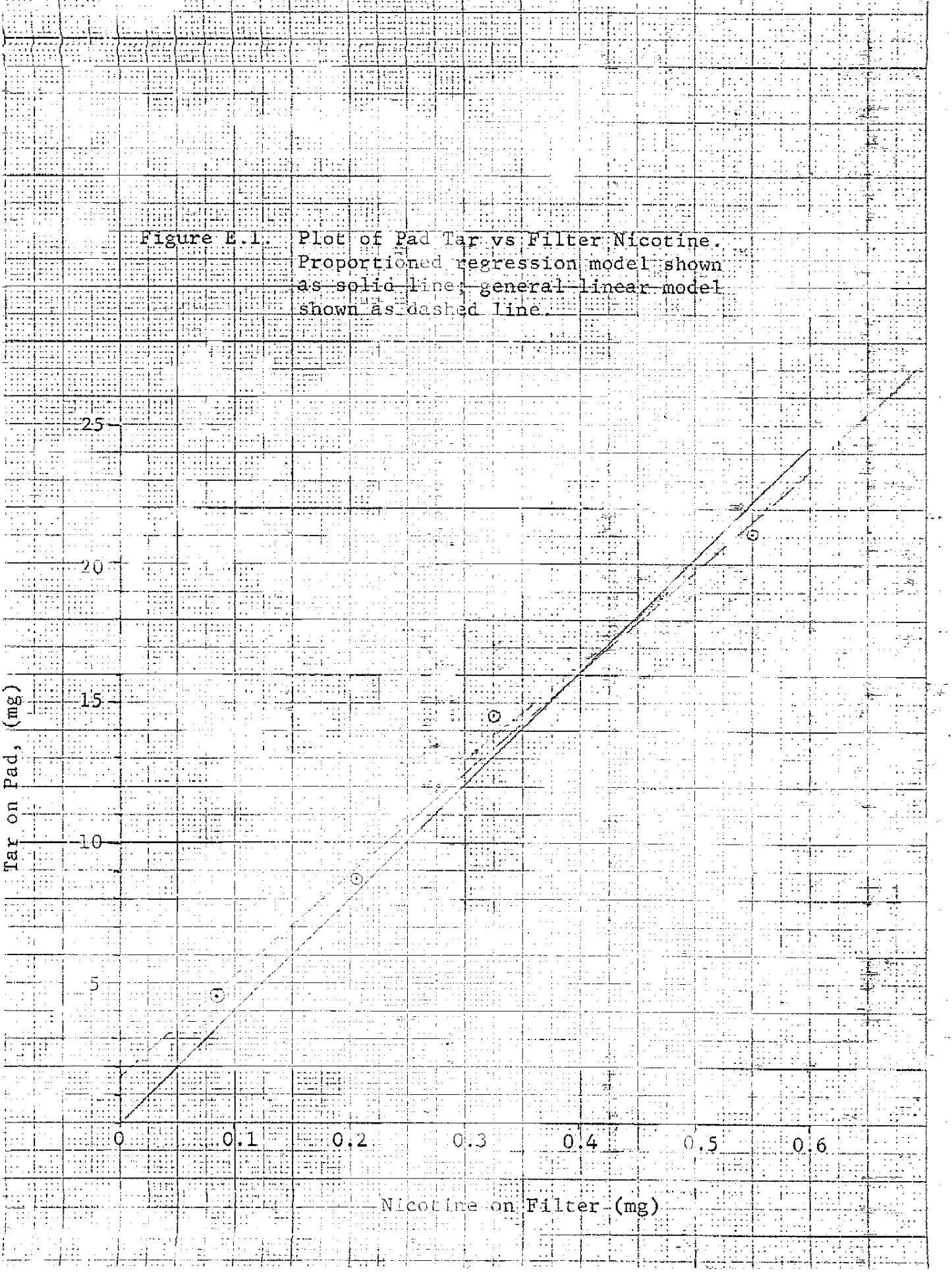
Figure E.1. Plot of Pad Tar vs Filter Nicotine. Proportioned regression model shown as solid line; general linear model shown as dashed line.



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m this, we may calculate the variance of a predicted value.

$$\text{Var}(\hat{\text{tar}})_{\text{pad}} = \text{Var}(\hat{\beta}) \times (\text{nicotine})^2_{\text{filter}} + (\hat{\beta})^2 \times \text{Var}(\text{nicotine})_{\text{filter}} + \text{Var}(\text{error})$$

: data, and results from fitting the model, gives

$$\text{Var}(\hat{\beta}) = 1.683/0.46^2 = 7.95, \quad \text{Var}(\text{error}) = 1.683$$

: coefficient of variability of a nicotine measurement, based on .lyzing five filters at a time, was shown in Section B.2 to average)ut 4.5%; thus

$$\text{Var}(\text{nicotine})_{\text{filter}} \approx (0.045)^2 \times (\text{nicotine})^2_{\text{filter}} \approx (0.002) \times (\text{nicotine})^2_{\text{filter}}$$

m this, the variance of a predicted pad tar may be calculated as

$$\text{ar}(\hat{\text{tar}})_{\text{pad}} = 7.95 + (40.32)^2 \times (0.002) \times (\text{nicotine})^2_{\text{filter}} + 1.683$$

$$= 11.24\ (\text{nicotine})^2_{\text{filter}} + 1.683$$

: results are shown below in Table E.2; the coefficient of variation

Table E.2. CALCULATED ERRORS OF PREDICTION

Butt ength (mm)	Predicted tar (mg)	Variance of Regression $(mg)^2$	Variance of Prediction $(mg)^2$	Standard Dev. of Prediction (mg)	C.V. (%)
70	3.46	.0831	1.766	1.3289	38.40
55	8.31	.4769	2.156	1.4683	17.66
40	13.06	1.1799	2.863	1.6920	12.96
27	22.18	3.4000	5.083	2.2545	10.16

a predicted value will be about 13% at the average butt lengths reported

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The estimate of tar for a 24-hour period will be obtained by summing imates of tar made from the results of nicotine analyses on groups k filters. Suppose that N cigarettes are smoked in 24 hours, so that re will be n = N/k groups of filters extracted and analyzed. Let c)$_i$ be the average nicotine content of the i^{th} such group, in mg/cig., ce i = 1, 2, ..., n. Let $(\overline{nic})$ denote the daily average,

$$(\overline{nic.}) = \frac{1}{n} \sum_{i=1}^{n} (nic.)_i .$$

:, let the variance of nicotine be denoted by

$$Var(nic)_i = \sigma_a^2 + \frac{\sigma_n^2}{k} ,$$

e σ_a^2 is the analytical error and σ_n^2 is the filter to filter varia-ty. We have also,

$$E\left[(nic)_i^2\right] = Var(nic)_i + E\left[(nic)_i\right]^2 .$$

estimate of total tar is given by

$$\begin{aligned} \hat{(\text{Total tar})} &= \sum_{i=1}^{n} k \text{ (estimates of tar from } i^{th} \text{ group)} \\ &= k \sum_{i=1}^{n} \hat{\beta} (nic.)_i \\ &= k \hat{\beta} \sum_{i=1}^{n} (nic)_i \\ &= N \hat{\beta} (\overline{nic}). \end{aligned}$$

variance of this estimate, from the above, is

$$Var[\hat{\text{Total tar}}] = k^2 \sum_{i=1}^{n} Var(\text{estimate of tar from } i^{th} \text{ group}),$$

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$$\text{Var}[\hat{\text{Total tar}}] = k^2 \sum_{i=1}^{n} \left\{ \left(7.95 + \frac{16.26}{n}\right)(\text{nic})_i^2 + 1.68 \right\}$$

$$= k^2 \left(7.95 + \frac{16.26}{n}\right) \sum_{i=1}^{n} (\text{nic})_i^2 + k^2 n\ 1.68$$

$$= k^2 \left(7.95 + \frac{16.26}{n}\right)(n)\left[\text{Var}(\text{nic})_i + E^2(\text{nic})_i \right]$$

$$+ kN\ 1.68$$

the square of the coefficient of variation of this estimate, ex-

sed as a fraction rather than as a percentage, is

$$\text{C.V.}^2[\hat{\text{Total tar}}] = \left\{ \frac{\left(7.95 + \frac{16.26}{n}\right)}{n\ 40.32^2} \left(\text{C.V.}^2(\text{nic})_i + 1\right) + \frac{1.68}{n\ 40.32^2\ (\overline{\text{nic}})^2} \right\} .$$

llustrate, let us assume a 40 mm butt length which gave, in Table

the value 0.324 for average filter nicotine content. The $\text{C.V.}^2(\text{nic})_i$

he equation is

$$\text{C.V.}^2(\text{nic}) = \frac{\sigma_a^2 + \sigma_{n/k}^2}{0.324^2} ;$$

value σ_a^2 is estimated from data given in Section II.B.2 to be $\sigma_a^2 \approx$

)1. The value of σ_n^2 may be estimated by

$$\sigma_n^2 \approx (\text{change of nicotine/change of butt length})^2 \times \text{Var(butt length)}$$

:e the slope, (change of nicotine/change of butt length) is estimated

n the data given in Table E.1 to be 0.012 mg/mm at or around the

rage value of butt length of 30 mm. Then,

$$\sigma_n^2 \approx (0.012)^2 \times 25 = 0.0036,$$

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:hat

$$C.V.^2(nic)_i = \frac{(0.0001) + (0.0036)/k}{0.324^2}$$

$$= [0.00095 + (0.034)/k] .$$

Thus, the C.V.^{2} (Total $\hat{}$ tar) may be written, approximately, as

$$.^2(\text{Total}\hat{}\ \text{tar}) \approx \frac{1}{n}\left[(0.005 + \frac{0.010}{n})\ (1 + \frac{0.034}{k})\ + 0.01\right]$$

sider a one pack per day smoker (N=20); the total tar estimate will
e the coefficients of variation, expressed as percentages shown below
various values of k, the number of filters analyzed together:

k	n	C.V.(%)
1	20	2.8
2	10	4.0
4	5	5.8
5	4	6.7
10	2	10.0
20	1	15.8

compositing of 4 or 5 filters would appear to give satisfactory pre-
.on.

Errors of Estimate, II. The analysis given in the last section based on the assumption that data would be available for estimation ; at several butt lengths. This may not be the case in a continua- ı of this study, particularly if the proportional model is verified subsequent analysis.

The data likely to be available may be described as follows. Each ıd will be tested only at FTC butt lengths (possibly in connection ı a study of FTC sampling methods). Filter nicotine and pad analyses

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l be made on composites of filters and pads from m ports, giving (20/m) replicates for each brand. Let $(nic.)_j$ denote the filter otine content of the j^{th} replicate, in (mg/cigarette), and let $(tar)_j$ ote the tar content of pads from the j^{th} replicate, in (mg./cigarette).

If the proportional model holds, then the parameter β may be esti- ed either by

$$\hat{\beta}_1 = \frac{\sum_{j=1}^{r} (nic.)_j \times (tar)_j}{\left[\sum_{j=1}^{r} (nic.)^2\right]} ,$$

ch is the least squares estimate, or by the estimator

$$\hat{\beta}_2 = \frac{\sum_{j=1}^{r} (tar)_j}{\sum_{j=1}^{r} (nic.)_j} ,$$

ch is the method of moments estimator. The two estimators would be ctly equal if the average values of filter nicotine from different ups of m cigarettes, all smoked to the FTC length, were exactly equal. estimators are also identical if, in addition to β being a straight e through the origin, the variance about the line is proportional to otine on the filter. These conditions may not hold in this case, ever, and the question of using the simpler ratio estimate, $\hat{\beta}_2$, is mined below.

The variances of these estimators, assuming that the values of $(nic.)_j$ known without error, are:

$$Var(\hat{\beta}_1) = Var\left[(tar)_j\right] / \sum_{j=1}^{r} (nic.)_j^2 ,$$

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$$\mathrm{Var}(\hat{\beta}_2) = \frac{r\ \mathrm{Var}(\mathrm{tar})_j}{\left(\sum_{j=1}^{r} (\mathrm{nic.})_j\right)^2} \quad .$$

ratio of these two variances gives some idea of the loss in effi-
ncy, under the above assumption, from using the simpler $\hat{\beta}_2$ rather than the
st squares estimator, $\hat{\beta}_1$; this ratio is

$$\frac{\mathrm{Var}(\hat{\beta}_2)}{\mathrm{Var}(\hat{\beta}_1)} = \frac{r \sum_{j=1}^{r} (\mathrm{nic.})_j^2}{\left[\sum_{j=1}^{r} (\mathrm{nic.})_j\right]^2} \quad .$$

$$(r-1)\left[\mathrm{Var}(\mathrm{nic.})_j\right] = r \sum_{j=1}^{r} (\mathrm{nic.})^2 - (\Sigma(\mathrm{nic.})_j)^2 \ ;$$

n

$$\frac{\mathrm{Var}(\hat{\beta}_2)}{\mathrm{Var}(\hat{\beta}_1)} = 1 + \left(\frac{r-1}{r^2}\right) \frac{\mathrm{Var}(\mathrm{nic.})_j}{\mathrm{Ave}(\mathrm{nic.})_j^2} \ ,$$

ere $\mathrm{Ave}(\mathrm{nic.})_j$ is the average value of nicotine. Now the variance,
$(\mathrm{nic})_j$, is merely σ^2/m, where σ^2 is the variance of nicotine in
.ters, from port to port. Thus,

$$\frac{\mathrm{Var}(\hat{\beta}_2)}{\mathrm{Var}(\hat{\beta}_1)} = 1 + \frac{1}{20}\left(1 - \frac{1}{r}\right) \frac{\sigma^2}{\left[\mathrm{Ave}(\mathrm{nic})\right]^2} \quad .$$

: example, some data are available on marketed brands which may be used
illustrate the values of the ratio. First, a 100 mm methalated ciga-
cte has $\hat{\sigma}^2 = 0.004$, ave(nic) = 0.41; this gives

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$$\frac{\text{Var}(\hat{\beta}_2)}{\text{Var}(\hat{\beta}_1)} = 1 + (1 - \frac{1}{r})\ (0.0012).$$

r r = 4,

$$\frac{\text{Var}(\hat{\beta}_2)}{\text{Var}(\hat{\beta}_1)} = 1.0009\ ;\quad \frac{\text{Std. Dev.}(\hat{\beta}_2)}{\text{Std. Dev.}(\hat{\beta}_1)} \approx 1.0045,$$

ich is small enough to be ignored. As another example, data for a atholated 85 mm cigarette gave $\hat{\sigma}^2 = 0.006$, Ave(nic.) = 0.9; the ratio even smaller.

Both estimators, $\hat{\beta}$, and $\hat{\beta}_2$, may contain some bias, if the assumptions ie above are not completely fulfilled. However, it is believed that ese biases are small enough to be ignored, generally.

Assuming that the second estimate is used, let us again examine ors of prediction. Let $(\text{nic.})_i$ denote the nicotine content, in mg/ lter, of a group of k filters analyzed together. Then, the estimate tar from the k cigarettes is

$$\text{(tar estimate for } i^{\text{th}} \text{ group)} = k\,\hat{\beta}_2(\text{nic.})_i,$$

that the error variance of an estimate of tar obtained from one group k composited filters will be

$$\text{Var(tar estimate from } i^{\text{th}} \text{ group)} =$$

$$k^2\left[\text{Var}(\hat{\beta}_2)\right]\left[E^2(\text{nic})_i\right] + \left[k^2\beta_2^2\right]\left[\text{Var}(\text{nic})_i\right] + \text{Error Variance.}$$

e error variance is merely the variability of pad tar among ports, σ_t^2, vided by the number of ports analyzed together, m:

$$\text{Error Variance} = \sigma_t^2/m.$$

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ariance of $\hat{\beta}_2$ was shown above to be

$$\mathrm{Var}(\hat{\beta}_2) = \frac{r\sigma_t^2}{m\left[\sum_1^r (\mathrm{NIC.})_j\right]^2} = \frac{\sigma_t^2}{20(\overline{\mathrm{NIC.}})^2} ,$$

$(\mathrm{NIC.})_j$ is the j^{th} value of filter nicotine, mg./cigarette, used rive the estimate $\hat{\beta}_2$ and $(\overline{\mathrm{NIC.}})$ is the average nicotine found:

$$(\overline{\mathrm{NIC.}}) = \left[\sum_{j=1}^r (\mathrm{NIC.})_i\right] /r.$$

fore, the variance of filter nicotine from filters collected during dy may be taken to be

$$\mathrm{Var}(\mathrm{nic}) = \sigma_a^2 + \frac{\sigma_n^2}{k} ,$$

ated from data to be

$$\mathrm{Var}(\mathrm{nic}) = 0.0001 + \frac{0.0036}{k} .$$

Var(tar estimate from i^{th} group) =

$$\frac{k^2\sigma_t^2E^2(\mathrm{nic})_i}{20(\overline{\mathrm{NIC.}})^2} + k^2\beta^2\left(\sigma_a^2 + \frac{\sigma_n^2}{k}\right) + \frac{\sigma_t^2}{m} .$$

fore, the estimate of total tar over the N cigarettes smoked in 24 is

$$(\hat{\mathrm{Total\ tar}}) = \sum_{i=1}^n (\text{tar estimate from } i^{th} \text{ group})$$

$$= \hat{\beta}_2 k \sum_{i=1}^n (\mathrm{nic.})_i$$

$$= N\hat{\beta}_2 (\overline{\mathrm{nic.}}),$$

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variation may be written as

$$C.V.^2\left[\hat{\text{Total tar}}\right] = \frac{1}{N}\left\{\frac{\sigma_t^2/4}{E^2(TAR)} + \frac{0.0008}{(3/4)^2E^2(NIC)} + \frac{\sigma_t^2/4}{5\beta^2E^2(NIC)(3/4)^2}\right\},$$

ce E(NIC) is the average filter nicotine concentration at FTC lengths, may thus be estimated from available data.

Value of $(\sqrt{N})(C.V.)$, expressed as a percentage, for eighteen brands cigarettes are shown below in Table E.3; also shown are the values of

Table E.3. TABLE OF $\sqrt{N}$ (C.V.) AND C.V. FOR 18 BRANDS AND FOR FOUR LEVELS OF SMOKING PER DAY

Brand	Length (mm)	Butt Length (mm)	$\sqrt{N}$ C.V.	Coeff. of Var., %, for various levels of smoking, in packs per day			
				1/2	1	1 1/2	2
1	85	27	6.53	2.0649	1.4601	1.1922	1.0325
2	85	27	6.12	1.9353	1.3684	1.1173	.9676
3	85	27	7.76	2.4539	1.7351	1.4167	1.2269
4	85	27	8.54	2.7005	1.9095	1.5591	1.3503
5	85	27	6.44	2.0365	1.4400	1.1758	1.0182
6	85	27	8.16	2.5804	1.8246	1.4898	1.2902
7	85	27	6.07	1.9195	1.3573	1.1082	.9597
8	85	33	9.28	2.9345	2.0750	1.6942	1.4673
9	85	27	6.88	2.1756	1.5384	1.2561	1.0878
10	85	27	6.01	1.9005	1.3438	1.0972	.9502
11	85	28	8.58	2.7132	1.9185	1.5665	1.3566
12	100	30	9.44	2.9851	2.1108	1.7235	1.4926
13	100	30	6.09	1.9258	1.3617	1.1119	.9629
14	100	33	6.16	1.9479	1.3774	1.1246	.9740
15	100	27	6.02	1.9036	1.3461	1.0991	.9518
16	100	27	5.48	1.7329	1.2253	1.0005	.8664
17	100	33	5.83	1.8436	1.3036	1.0644	.9218
18	100	27	6.50	2.0554	1.4534	1.1867	1.0277

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:oefficients of variation for various smoking levels per day. All values
f coefficients of variation seem to be low enough to provide strong
ncouragement to continue the study. It is interesting to note that the
ix 100 mm brands have an average coefficient of variation which is about
2% of the average coefficient of variation of the 85 mm brands.

Source: https://www.industrydocuments.ucsf.edu/docs/yxgk0001

titute Testing Laboratory (TITL)) and from a knowledge of nicotine
ter efficiency for each brand. This is true, but the possibilities
errors in such a procedure lead to the suggestion that a more direct
hod of obtaining the ratios would be to simply conduct filter nicotine
lyses on the next market sample tested by TITL. The filter nicotine
ues so obtained should be determined by the AutoAnalyzer method, as
t would be the method which would seem to be the most feasible for
tine use in a large survey of tar delivery. In a 200 brand market
ple study by TITL, there will be 200 x 20 = 4000 groups of five filters;
ters from up to five ports for each brand could be composited to re-
e the analytical work load downward to 800 analyses. This is a large
ber of analyses, but certainly not unmanageable.

Source: https://www.industrydocuments.ucsf.edu/docs/yxgk0001

III. PROPOSED FIELD INVESTIGATIONS

DEFINITION OF THE PROBLEM

The overall objective of the proposed research is to determine if posure to smoke per unit time period, say a day, is related to initial ngth of the cigarette. Of specific interest is a comparison of the erage exposure of individuals who smoke 100 mm cigarettes with that of dividuals who smoke 85 mm cigarettes. Exposure is defined herein as e delivery of FTC tars.

It is recommended that the work on this project proceed in three ases. After each phase there will be an opportunity to assess the sults of the investigation to date and to make recommendations for sub-quent phases. The first phase was the feasibility study reported in ction II. The principal conclusion of that analysis is that it is deed feasible to use nicotine measured in the filter to estimate FTC rs.

On the basis of those results, it is recommended that a pilot inves-gation be undertaken to gain experience in coordinating the field pro-dures (primarily butt collection) with office and laboratory procedures rimarily measurement of information in the filter). The specific jectives of phase II are

1. to determine if the field, office and laboratory procedures are compatible,
2. to test the effect of daily pickup versus five-day pickup and ten-day pickup, and
3. to test the effect of a gift incentive on the respondent's

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otivation to cooperate.

period when the pilot study is being conducted, certain tests
in Section II.F could also be performed. Plans for a more
study would then await the results of the pilot investigation.
ended pilot study is described in Section III.B and the
ime schedule is given in Figure III.B.1.

gh the procedure outlined above is recommended, it is doubtful
sizes are sufficient to demonstrate differences between ex-
hose smoking 100 mm and those smoking 85 mm if such differences
sponsor has suggested that it might be desirable to enlarge
f the pilot investigation so that reliable estimate of 100 mm
oking exposures might be obtained for a limited but well
verse. The study should be designed so as to gather information
the objectives mentioned previously in this section as well.
ed study, entitled "Field Investigation to Obtain Preliminary
osure Estimates by Individual" is described in III.C.

ETHODOLOGICAL FIELD INVESTIGATION

tion of the Universe. Since this is to be a pilot study to
tain aspects of the methodology, the definition of the universe
importance than it would be for a more comprehensive survey
obtain substantive data. Criteria in the selection of the
are

ban area and surrounding rural area,

arness to RTI,

ban area must not contain a tobacco industry,

ban area should have had a recent census,

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5. availability of block statistics in the urban area,

6. test of a gift incentive versus no gift incentive.

nsideration of these criteria led to a tentative selection of High Point
l surrounding rural area and Fayetteville and surrounding rural area.
Fayetteville is adopted, soldiers would be ruled ineligible for the
lot study.

2. Sample Design. The sample will be a stratified random sample of
ea sampling units each of which will contain, on the average, approxi-
ely five 1960 occupied dwelling units. All cigarette smokers who
side in these areas would be eligible for the sample. The exception to
s eligibility rule will be soldiers and workers in a tobacco industry.

It is proposed to select enough sampling units to yield approximately
) smokers. A preliminary examination indicates this may require approxi-
ely 48 area segments. These sampling units will be allocated as follows:

12 to High Point City,

12 to rural area around High Point, boundaries of the area
to be defined,

12 to Fayetteville City,

12 to rural areas around Fayetteville, boundaries of the
area to be yet defined.

The sample is to be further subdivided by number of times butts are
be picked up and by types of incentive. The numbers in the cells of
e following table indicate the expected number of smoker participants.

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	Urban		Rural		
	Fayetteville (no gift incentive)	High Point (gift)	Cumberland County (no gift incentive)	Guilford County (gift)	Total
ction	30	30	30	30	120
ction at intervals	15	15	15	15	60
ction at 10-day	15	15	15	15	60
	60	60	60	60	240

Field Procedures. The selected areas will be visited and an initial eening schedule will be administered to a responsible member of each ple household to determine smokers. Once a smoker in the sample segment been identified, a short questionnaire will be administered to elicit e additional information. The questionnaire will be fairly short and l include such questions as basic demographic information, average amount ked per day, length of time smoked, present brand, and length of time as been smoked. At the time, a promise of cooperation will be sought an appointment made for a revisit. Those who are scheduled to receive ntive gifts will be so notified at this time.

If no responsible adult is home at the time of the first visit, a nd visit will be made, preferably at a different time of the day. If second visit is likewise not successful, a third call will be made. If ne can be interviewed on the third call, the household will be classi- as a no-contact non-respondent.

Once the subject has agreed to participate, he will be visited again hich time he will be provided with

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will be given a portable ash tray to carry with him wherever he goes
d will be asked to deposit all butts in it for the period from 6:00 p.m.
e day to 6:00 p.m. the following day. After 6:00 p.m. he will be asked
deposit them in a container marked for that date and seal the container.
the same time he will be asked to complete a short diary. The main
rpose of this diary will be to ask him to record the number of cigarettes
smoked that day and the brand(s) by type of environment and the length
time exposed to that environment. For example, the number smoked

1. While at work,
2. While commuting to and from work,
3. While at home,
4. While attending a social function,
5. Other.

he should have inadvertently missed putting a cigarette butt in the can,
should so indicate in the proper place on the diary page.

He will be asked to conduct the study for ten days. One tenth of
subjects will be started on each of ten days so that the whole field
eriment will run for 20 days. On half of these, the interviewers will
k up the containers for that day each day.

Half of the remainder will be visited at the end of 5 days and again
the end of 10 days. The final 1/4 will be contacted only at the end of
10th day.

There will be a final inverview at the end of the period which will
in the nature of a critique of the study. Those who are to receive in-
tive gifts will get them at the time of the final interview.

. Office Procedures.

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General

The containers will be delivered and logged in at the office. The rst step will be to separate the cigarettes in each container by brand d record the number of each. Where possible, two samples of five each ll be selected at random. Where there are less than ten butts, they will divided equally into the two samples.

Filter Cigarettes

On one sample of five, the remaining tobacco will be separated from e filter at their interface. Each part will then be slit lengthwise with razor blade; the part containing tobacco will be slit completely and the bacco removed. The paper will be smoothed out and the length at the ortest point will be measured in mm. The part containing the filter will partially split to prepare it for the laboratory process.

The two samples will be marked for identification; and the remainder ll be marked in the same manner stored for possible future use. The two mples will then be taken to the laboratory.

Non-filter Cigarettes

Non-filter cigarettes will be counted and butt lengths measured on sample selected in the same manner as for filters. No chemical measure- nts will be made until more reliable laboratory techniques can be per- cted.

5 Laboratory Procedure. The laboratory procedure which applied only filters, will follow as closely as possible the routines established the company laboratories. Both samples will be treated, their solution asured and results recorded. If a sample has less than five filters, the

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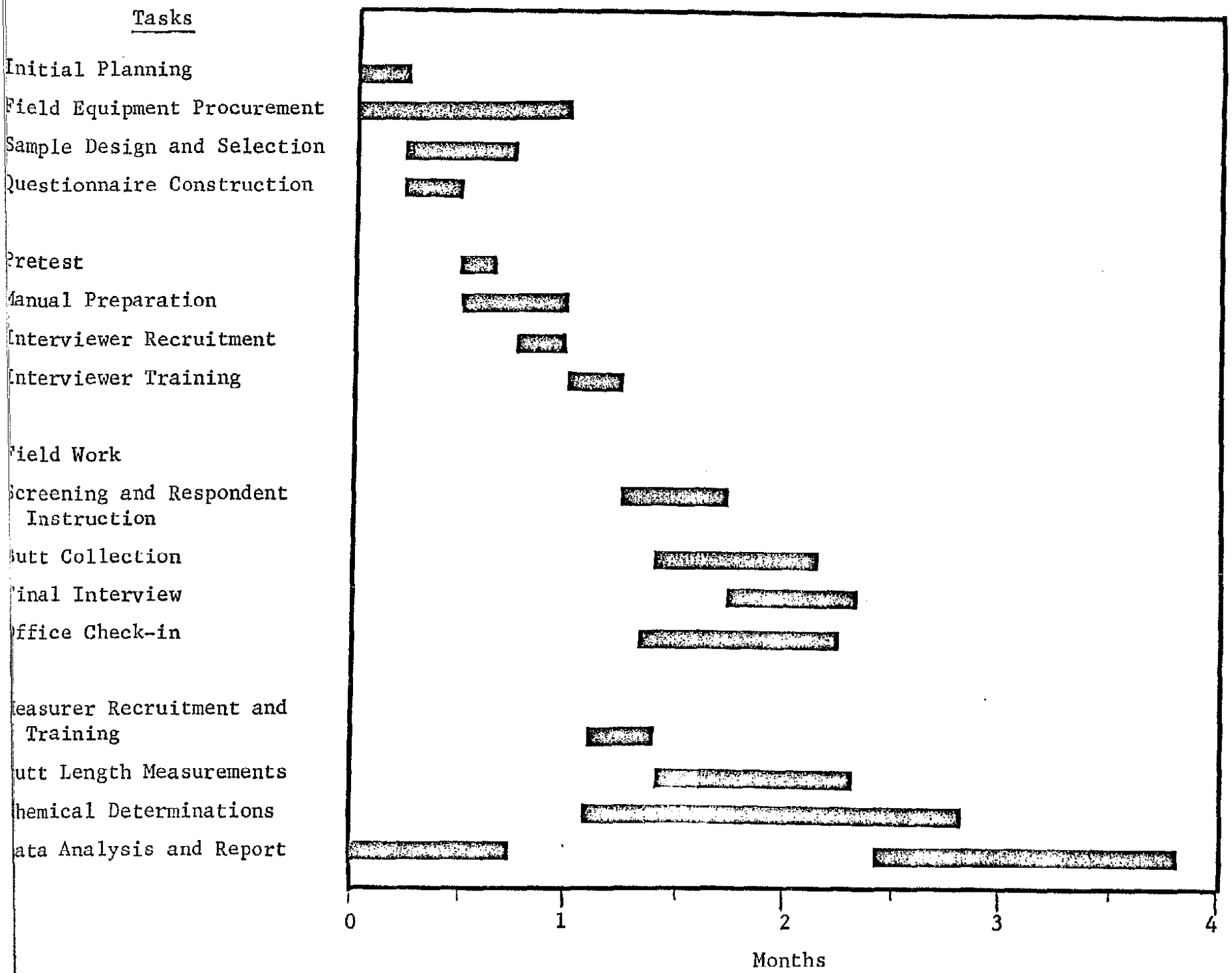
mber must be recorded also. If all 240 individuals save butts each day r ten days and we select two samples from each, approximately 3400 tests r nicotine would need to be run assuming 70% filter smokers. This mber could be decreased by natural attrition or increased by persons oking more than one brand.

6. Data Analysis. It is assumed that the special tests recommended ove in Section II.F will be conducted; the results from these tests will analyzed as soon as possible. It is anticipated that the results from se tests will allow the errors of estimation to be studied in more ail than was possible using the data described in this report. From s, a final summary can be prepared of the prediction errors and sses to be expected from the survey.

Next, it is assumed that the TITL-like tests will have been run; this a will be analyzed. The factors (denoted as $\hat{\beta}$ in Section II.E) and ir variances will be derived.

From the survey results, the butt length data, nicotine data, and ly tar estimates will be summarized and analyzed, and standard devia- ns of estimated daily tar delivery calculated. In addition, survey edures will be reviewed, diarys will be reviewed for completeness and results will be assessed against the population (rural/urban) and nst the gift incentive. Effects of different pick-up schedules will stimated. The results will be summarized, with recommendations, into nal report.

Source: https://www.industrydocuments.ucsf.edu/docs/yxgk0001



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FIELD INVESTIGATION TO OBTAIN PRELIMINARY SMOKING EXPOSURE ESTIMATES *BY INDIVIDUALS*

.1. Definition of the Universe. The definition of the universe is some-
nat arbitrary. It should be explicitly defined geographically and then
nould include all cigarette smokers who reside within those geographic
imits. Since the objectives of this study are both to test methodology
id to obtain some preliminary estimates of smoking exposure, a geographic
iiverse near RTI should be selected to hold travel costs to a minimum.
: is therefore suggested that the universe be defined as those counties
mprising the Piedmont Section of North Carolina.

2 Sample Design. An area sample with the sampling units selected at
ndom from geographic strata is again recommended. Each sampling unit
.11 contain, on the average, approximately five 1960 occupied dwelling
iits. All cigarette smokers who reside in the area sampling units are
.igible for the sample.

A stated objective of this field study is to obtain separate estimates
' smoking exposure for 85 mm smokers and for 100 mm smokers. The relevant
estion here is concerned with the number of smokers that will be required
: order to test the hypothesis that smoking exposure does not differ more
an a certain specified amount for smokers of the two lengths.

Many assumptions must be made. First, what difference should it be
asonable to try to detect? The answer to this question is somewhat
bitrary also but might be based on the average differences in tar deliv-
y when smoked to FTC length. Liggett and Myers tested ten brands of
's and seven brands of 100's. The unweighted means were 19.9 mgs for
e 85's and 22.9 mgs for the 100's giving an average difference of 3.0

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mgs of FTC tar per cigarette. The limited information we have indicates that average butt length for 85 mm may be about 40 mm. It was also stated in Section E.2 that the average smoker might have a nicotine delivery approximately 75% of that delivered at FTC length. Hence, one value of an average difference to be detected might be 75% of 3 mgs or 2.25 mg.

Estimates of the variance of the mean FTC tar delivery are not available for either 85 mm or 100 mm. Some information is available on the variability of total tar per day per individual smoker, given the number of cigarettes smoked per day. However, there are no estimates on the mean number smoked by the two groups. In the absence of such information, it is assumed that the variances of the means for smokers of the two lengths are eseentially equal.

The derivation of the formula required to estimate sample size is shown in the appendix. Also shown is a table that estimates the required sample size for variance values of the average difference to be detected. If a difference of 2.25 mg per cigarette per day is to be detected, approximately 1430 individuals (715 for each length) will be required. This should be rounded to 1500 to allow for lack of precise estimates.

C.3 Field Procedures. The field procedures will be similar to those reported in III.B.3 with one exception. Since different proportions of smokers smoke 100 mm filters, 85 mm filters and non-filters, and since we want approximately equal numbers of individuals smoking 85 mm filters and 100 mm filters, some preliminary screening must be employed. Available estimates indicate that approximately 60% smoke 85 mm filters, 12% 100 mm filters, and 28% non-filters.

Roughly, the screening procedure would be to take all 100 mm smokers

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Yes?

in the sample, take 1/2 of non-filter smokers, and take 1/5 of 85 mm smokers. The screening schedule can be prepared to accomodate these sampling fractions. Of course, the proportions can be adjusted in the field if these estimates are no longer accurate or if they fail to reflect the true proportions in the selected universe.

The methods of collection and the gift incentive techniques can also be tested with this sample. However, until sample size (and mean difference to be detected) is specified, the exact procedure cannot be detailed.

C.4 Office Procedures. The office procedures will be the same as those specified for the pilot investigation.

C.5 Laboratory Procedures. Standard analytical chemical laboratory procedures will be followed. Based on an estimated sample size of 750 85 mm and the same number 100 mm smokers, approximately 30,000 tests for nicotine must be run.

C.6 Data Analysis. If this investigation is carried out, the data analysis procedures described in Section III.B.6 will also apply here; in addition, a test of difference in mean daily tar delivery between 85 mm smokers and 100 mm smokers will be conducted on the data.

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APPENDIX

DEVELOPMENT OF SAMPLE SIZER FOR TESTING DIFFERENCES IN TAR DELIVERY IN FIELD INVESTIGATIONS.

Let T_{ij} be the estimate of daily tar delivered to the i^{th} smoker, smoking brand j, derived from some test program. Assume that there are m smokers in the test. Divide the brands into two classes: 85 mm brands and 100 mm brands. Suppose m_1 individuals smoke 85 mm brands and m_2 smoke 100 mm brands and that these are the only lengths tested so that $(m_1 + m_2) = M$. If we let j = 1 denote 85 mm brands and j = 2 denote 100 mm brands, then $\sum_{i=1}^{m} T_{i1}/m_1$ will be the daily tar delivery from 85 mm brands, averaged over the m_1 smokers smoking such brands, and

$$\hat{\Delta} = \frac{\sum_{i=1}^{M} T_{i1}}{m_1} - \frac{\sum_{i=1}^{M} T_{i2}}{m_2}$$

will be the average difference in daily tar delivery between 85 mm brands and 100 mm brands.

The variance of the difference is

$$\text{Var}\,(\hat{\Delta}) = \frac{\text{Var}\left[\sum_{i=1}^{M} T_{i1}\right]}{m_1^2} + \frac{\text{Var}\left[\sum_{i=1}^{M} T_{i2}\right]}{m_2^2} .$$

But

$$\text{Var}\left[\sum_{i=1}^{M} T_{ij}\right] = \sum_{i=1}^{M} \text{Var}(T_{ij}) = m_j \text{ Var } (T_{ij}),$$

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so that

$$\text{Var}\ (\hat{\Delta}) = \frac{\text{Var}(T_{i1})}{m_1} + \frac{\text{Var}\ (T_{i2})}{m_2} .$$

One may test the significance of the difference by forming the ratio

$$\hat{\Delta} \Big/ \sqrt{\text{Var}\ (\hat{\Delta})} ,$$

and equating this to the critical value from the Student-t distribution with (M-2) degrees of freedom; alternately, one may use this fact to determine the sample size required to demonstrate the significance of a preassigned difference Δo. It is this latter case in which interest is centered here.

Let $m_1 = m_2 = m$. Then the variance may be written as

$$\text{Var}(\hat{\Delta}) = \frac{1}{m} \left[\text{Var}(T_{i1}) + \text{Var}(T_{i2})\right] ,$$

where, as implied before, $\text{Var}(T_{ij})$ is the variance of the estimate of daily tar delivery, T, from a randomly selected smoker (i) smoking brand j. Thus the ratio may be written as

$$\frac{\sqrt{m}\Delta o}{\sqrt{\text{Var}(T_{i1}) + \text{Var}(T_{i2})}} = t_{2m-2,\ 1-\alpha} ,$$

from which

$$\sqrt{m} = \frac{t\sqrt{\text{Var}(T_{i1}) + \text{Var}(T_{i2})}}{\Delta o}$$

gives the size of sample required to detect the difference Δo.

From available data on characteristics of smoking [2], it is estimated that the number of cigarettes smoked per day by the smoking public averages about 17, and the variance of number of cigarettes smoked per day is about 99. From Section II.E.2, we have

$\sigma^2 = 99$

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$$T_{ij} = \sum_{l=1}^{n} (\text{tar estimate from } \ell^{th} \text{ group})_{ij} ;$$

that is, the estimate T is the sum of estimates over the n groups of cigarettes smoked per day. Since k is the number of cigarettes grouped for analysis, the average value of n is (17/k) and the variance of n is $(99/k^2)$. We then have

$$\text{Var}(T_{ij}) = E(n)\text{Var}(\text{tar estimate from } \ell^{th} \text{ group})_{ij} + \text{Var}(n)\, E^2(\text{tar estimate from } \ell^{th} \text{ group})_{ij} .$$

But

$$\text{Var}(\text{tar estimate from } \ell^{th} \text{ group}) = k\left[\frac{k\sigma_t^2 E^2(\text{nic})}{20(\overline{\text{NIC}})^2} + k\beta^2\left(\sigma_a^2 + \frac{\sigma_n^2}{k}\right) + \frac{\sigma_t^2}{km}\right],$$

and

$$E(\text{tar estimate from } \ell^{th} \text{ group}) = k\beta E(\text{nic}),$$

so that the variance of Tij from a randomly selected smoker is

$$\text{Var}(T_{ij}) = kE(n)\left[\frac{k\sigma_t^2 E^2(\text{nic})}{20(\text{NIC})^2} + k\beta^2\left(\sigma_a^2 + \frac{\sigma_n^2}{k}\right) + \frac{\sigma_t^2}{km}\right] + k^2 V(n)\left[\beta^2 E^2(\text{nic})\right].$$

The first term in square brackets on the right hand side of the equation given above is equal to (1/N) times the equation for $\text{Var}(\widehat{\text{Total tar}})$ given on the top of page 63. Noting that the [kE(n)] multiplier for the first term in square brackets above is merely the expected number of cigarettes per day, it is seen that the equation for $\text{Var}(T_{ij})$ given above is the sum of two parts:

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Source: https://www.industrydocuments.ucsf.edu/docs/yxgk0001

a) the first part, equal to the variance conditional on a fixed number of cigarettes N smoked per day, which is the same as derived in Section II.E,

b) a second part, proportional to the variance of N.

Let CV denote the coefficients of variation defined on the bottom of page 63 and given in Table E.3; then

$$\mathrm{Var}(T_{ij}) = E^2(T_{ij}) \left[CV^2 + \frac{V(N)}{E^2(N)} \right],$$

and for $E(N) \approx 17$ cigarettes, we have $[V(N) / E^2(N) = 0.364]$. From Table E.3 and from the formula given above, we have

$$\mathrm{Var}(T_{ij}) = E^2(T_{i1}) \times 1.86 \text{ for 85 mm cigarettes,}$$

$$= E^2(T_{i2}) \times 1.66 \text{ for 100 mm cigarettes,}$$

where the values are averaged over all 85 mm and 100 mm cigarettes given in Table E.3.

Thus,

$$V(\hat{\Delta}) \approx 1.86\, E^2(T_{i1}) + 1.66\, E^2(T_{i2}).$$

The average tar, at FTC test lengths, for 85 mm cigarettes is 19.9, so that the daily FTC tar delivery (from 17 cigarettes) would be 338.3 mg. The same value for 100 mm cigarettes is 389.3 mg. Thus, at FTC test lengths,

$$V(\hat{\Delta}) \approx 464{,}451 \text{ mg}^2$$

If we assume that the average smoker will smoke to a length which gives 75% of the FTC tar (based on data given in Part II), then the variance at this level is

$$\mathrm{Var}(\hat{\Delta}) \approx 261{,}253,$$

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$$\sqrt{\text{Var}(\hat{\Delta})} \approx 511.$$

Thus, taking t = 2, we have

$$\sqrt{m} = \frac{(2) \times (511)}{\Delta o} = \frac{1022}{\Delta o} .$$

Values of m, the number of individuals tested per group, and M = 2m, the total sample size, are given below for various values of Δo, the mean difference in daily tar delivery which it is desired to detect.

Difference in daily tar delivery to be detected.		Number of individuals tested for each length(m)	Total sample size for two lengths (M)
mg per day	mg per cigarette(1)		
15	0.88	4640	9280
20	1.18	2610	5220
25	1.47	1670	3340
30	1.76	1160	2320
35	2.06	850	1700
38.25(2)	2.25(2)	715	1430
40	2.35	650	1300
45	2.65	520	1040
50	2.94	420	840

(1) Assuming 17 cigarettes smoked per day.

(2) Difference suggested as standard for which sample sizes are chosen. See III.C.2.

→ 45.

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REFERENCES

[1] W. Haenszel, M. B. Shimkin and H. P. Miller: Tobacco Smoking Patterns of the United States; Public Health Monograph #45, May 1956, Government Printing Office, Washington, D. C.

[2] Cigarette Smoking and Health Characteristics, National Center for Health Statistics Publication Series 10, No. 34; May 1967, Government Printing Office, Washington, D. C.

[3] E. C. Hammond: "Lung Cancer Death Rate in England and Wales Compared with those in the U.S.A.", British Medical Journal, September 13, 1958, Pages 649-654.

[4] A. L. Finkner, et.al: Methods of Measurement of Current Smoking by Individuals; North Carolina Agricultural Experiment Station, Technical Publication # 127, June 1961.

[5] A. C. Hilding: "On Cigarette Smoking, Bronchial Carcinoma and Ciliary Action"; New England Journal of Medicine, Vol. 254, No. 17, April 26, 1956, Pages 775-781.

PM3001148251

Source: https://www.industrydocuments.ucsf.edu/docs/yxgk0001